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THE
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VOL. XXXV. NOVEMBER, 1913. No. 1.

THE ROASTING OF COPPER-NICKEL MATTE.

BY EDWARD F. KERN AND M. H. MERRIS.

The treatment of copper-nickel ores and mattes by pyro-metallurgical methods is either accomplished, or else accompanied, by oxidation reactions. The reactions which take place during the roasting are in most cases identical to those which occur during the smelting of the ores and during the converting of the matte. This is also the case when oxides of copper are reduced, which is accomplished by the oxidation of the reducing material, generally sulphide ores or matte.

On account of the importance which oxidation reactions play in the metallurgy of copper-nickel ores and mattes, and the variance in the published data on the subject, a further study of the roasting of copper-nickel mattes was conducted. An account of a previous study was published in the SCHOOL OF MINES QUARTERLY, XXXII, pp. 364 to 388 (July, 1911), and as several important reactions were not investigated at that time, the work was continued. These reactions are those which occur (1) when oxide of copper is heated in contact with either sulphide or sulphate of nickel; (2) when oxide of nickel is heated in contact with either sulphate or sulphide of copper; the temperature necessary to bring about reaction was also investigated. With these questions answered, and with more knowledge of what occurs during the roasting of a copper-nickel matte, which is performed by slow oxidation, a better understanding will be gained of what takes place during the smelting of copper-nickel ores, and in the converting of copper-nickel mattes, both of which are accomplished by reactions which are similar to those which occur during roasting, but are more rapid.

Abstract of Literature.

Since the publication of the article by Kern and Walters (School of Mines Quarterly, XXXII, 364) very little has appeared in the literature on the treatment of copper-nickel ores or mattes, but in order to have direct reference to that information, an abstract is given below.

Nickel oxide and nickel sulphide do not react upon each other. Nickel oxide and copper sulphide do not react. (Schnabel-Louis "Handbook of Metallurgy" II, 630, 1907 Ed.)

By carefully roasting a mixture of nickel and copper sulphides, it is possible to get nickel monoxide and cupric oxide, or a mixture of oxides and sulphates of nickel and copper. As nickel sulphate is stable at a higher temperature than copper sulphate, it is possible, with a sufficient proportion of sulphur in the ore, to conduct the roast so that nickel remains chiefly as sulphate, and the copper as oxide. (Schnabel-Louis "Handbook of Metallurgy" II, 631, 1907 Ed.).

According to Schweder (Schnabel-Louis "Handbook of Metallurgy" II, 632, 1907 Ed.), sulphide of nickel and cupric oxide react at elevated temperatures, as indicated by the reactions:

$$4CuO + 4NiS = 2Cu_2S + (NiS.Ni) + 2NiO + SO_2$$
$$4CuO + 2NiS = Cu_2S + 2Cu + 2NiO + SO_2$$
$$4CuO + (2NiS.2Ni) = Cu_2S + 2CuNi + 2NiO + SO_2$$

The decomposition temperature of iron sulphate, copper sulphate, and nickel sulphate have been determined by the following:

R. H. Bradford found that $FeSO_4$ decomposed at 590°C., $CuSO_4$ at 650°C., and $CuO.CuOS_4$ at 702°C. These determinations were made by heating the dehydrated sulphates in porcelain crucibles in an accurately controlled electric resistance furnace, having the junction of a platinum and platinum-iridium thermo-couple imbedded in the sulphates. By noting the temperature at which there was a retardation in the progressive rise in temperature, the temperature of the decomposition was found. (*Trans.* Amer. Inst. Min. Eng. XXXIII, 50. 1903).

Walters determined the decomposition temperatures of ferrous sulphate, copper sulphate, and nickel sulphate, by heating the dehydrated sulphates in a closed porcelain tube which was connected with a manometer. By heating the tube in an electric furnace with

uniform rise of temperature, and noting the temperature at which the manometer column recorded a sudden abnormal rise, which was due to the evolution of SO_3, the temperature of decomposition of the sulphate was determined. Ferrous sulphate was found to change into the basic sulphate at temperatures above 280°C., to decompose into a more basic sulphate at about 520°C., and to change entirely into ferric oxide above 580°C. Copper sulphate does not form basic sulphate by heating below its decomposition temperature, which was found to be about 640°C. Nickel sulphate is not broken into a basic sulphate, unless heated above its decomposition temperature, which was found to be about 730°C. (SCHOOL OF MINES QUARTERLY, XXXII, pp. 368 to 374. 1911.)

Landis found the decomposition of ferrous sulphate to be slight at 550°C., to increase up to 580°C., and to become more rapid up to 600°C., " when there was a sudden increase." Copper sulphate showed a very slight decomposition between 400 and 690°C.; at the latter temperature rapid decomposition took place. (*Metallurgical and Chemical Engineering*, VIII, 22. 1910.)

Hofman and Wanjukow heated a number of metallic sulphates in a current of dry air, and noted the temperature at which they lost weight. They started with the crystallized salts. (*Trans.* Amer. Inst. Min. Eng., XLIII, 1912, 536, 547, 555.) The following data for the sulphates of iron, copper, and nickel are given:

$FeSO_4.7H_2O$ heated at 80°C. changes to $FeSO_4.H_2O$ and $6H_2O$.
$FeSO_4.H_2O$ heated at 450°C. changes to $Fe_2O_3.2SO_3$ and SO_3.
$Fe_2O_3.2SO_3$ heated at 560°C. changes to Fe_2O_3 and SO_3.
$FeSO_4$ heated at 480°C. changes to $Fe_2O_3.2SO_3$ and SO_3.
$CuSO_4.5H_2O$ heated at 95°C. changes to $CuSO_4.H_2O$ and $4H_2O$.
$CuSO_4.H_2O$ heated at 160° C. changes to $CuSO_4$ and H_2O.
$CuSO_4$ heated at 340° C. changes to $8CuO.3SO_3$ and SO_3.
$CuSO_4$ heated at 670°C. changes to $2CuO.SO_3$ and SO_3.
$2CuO.SO_3$ heated at 730°C. changes to $2CuO$ and SO_3.
$NiSO_4.7H_2O$ heated at 105°C. changes to $NiSO_4.H_2O$ and $6H_2O$.
$NiSO_4.H_2O$ heated at 280°C. changes to $NiSO_4$ and H_2O.
$NiSO_4$ heated at 760°C. changes to NiO and SO_3.

David H. Browne, who studied the behavior of copper-nickel matte in the operation of converting it to metal (*Trans.* Amer. Inst. Min. Eng., XLI, pp. 296 to 316. 1910), stated that formerly nickel was regarded as an element replacing iron in copper-nickel mattes, but the more recent theory is that nickel is more closely associated

with copper in mattes than it is with iron. The conclusions which were drawn from the results of a long series of experiments on the converting of Sudbury copper-nickel mattes are as follows: Nickel is not an element replacing iron in mattes. Nickel-copper alloys act in the matte-blow like one metal, and follow the same laws as govern the behavior of copper alone. Nickel does not, as previously supposed, follow iron into the slag, but displays a reluctance to part with copper, so much so that 1 lb. of nickel passing into the slag drags 1.25 lb. of copper with it. While nickel, during the last of the blow, does oxidize, yet it lags behind sulphur as a heat producer, The final product of blowing a copper-nickel matte is one homogeneous metal, no matter whether high copper and low nickel, or vice versa. Nickel exists in mattes as subsulphide (Ni_2S) and not as monosulphide (NiS).

Walters determined the freezing points of copper sulphide, nickel sulphide, and mixtures of the two in definite proportions. Cuprous sulphide solidified at 1110°C. Nickel sulphide, of the composition corresponding to Ni_5S_4, solidified at 790°C. A mixture of 64 parts by weight of cuprous sulphide and 36 of nickel sulphide (Ni_5S_4) began to solidify at 948°C., when the excess of cuprous sulphide separated, after which the eutectic froze at about 740°C. A mixture of equal parts by weight of cuprous sulphide and nickel sulphide (Ni_5S_4) began to solidify at 900°C., when the excess of cuprous sulphide started to freeze, after which the eutectic froze at about 740°C. A mixture of 40 parts by weight of cuprous sulphide and 60 parts of nickel sulphide (Ni_5S_4) was found to be the eutectic which froze at about 740°C. (SCHOOL OF MINES QUARTERLY, XXXII, 387. 1911.)

I.—THE SEPARATION AND DETERMINATION OF COPPER AND NICKEL.

Separation of Copper and Nickel.—As no reliable method could be found for separating the sulphates, oxides, and sulphides of copper and nickel from mixtures containing all of these salts, it was found necessary to select solvents which would separate the sulphates from the oxides, and the oxides from the sulphides. The separation of the sulphates from the oxides and the sulphides was easily accomplished by leaching with hot water, but no solvent was found which would completely dissolve nickel oxide and not attack nickel sulphide. The solvents tried were solutions of ammonia,

various concentrations of ammonia solutions containing ammonium chloride, dilute solutions of hydrochloric acid, and dilute sulphuric acid.

Solutions of ammonia and of ammonia containing ammonium chloride dissolved cupric oxide, but did not dissolve nickel oxide, nor did they attack nickel sulphide (Ni_5S_4) nor cuprous sulphide. Dilute hydrochloric acid, containing so small an amount as 0.5 c.c. concentrated acid (sp. gr. 1.2) per 100 c.c. water, dissolved nickel oxide, nickel sulphide (Ni_5S_4), and cupric oxide, but did not attack cuprous sulphide. On account of the insolubility of nickel oxide in solutions of ammonia and of ammonia containing ammonium chloride, and the solubility of nickel sulphide in very dilute hydrochloric acid, none of these solutions could be used for the separation of nickel oxide from nickel sulphide.

Dilute sulphuric acid proved to be less energetic than dilute hydrochloric acid as a solvent of nickel sulphide, and a good solvent of both copper oxide and nickel oxide. The tests were made by digesting 0.25-gram samples of fused cuprous sulphide, fused nickel sulphide, ignited copper oxide, and nickel oxide with sulphuric acid of different dilutions and at different temperatures for periods of 10 to 30 min. It was found that both nickel oxide and copper oxide are completely soluble in dilute sulphuric acid, cuprous sulphide is not attacked, and that the amount of nickel sulphide dissolved depends upon the strength of the acid used, the time of the digestion and the temperature of the solution. When boiling, dilute acid, containing more than 1.5 c.c. of concentrated sulphuric acid per 100 c.c. of water, was used for digesting the samples of nickel sulphide for periods of 10 to 25 min., the amount of nickel dissolved was from 8 to 25 percent. of the total nickel in the sulphide. By using 150 c.c. of dilute acid, containing 0.5 c.c. concentrated sulphuric acid per 100 c.c. of solution, at temperatures between 80 and 95°C., the amount of nickel dissolved in 30 min. from the nickel sulphide was from 3 to 4 percent. of the total amount in the samples.

Samples of the raw matte were next digested with dilute sulphuric acid of the same concentration as that used on the fused nickel sulphide. The results were the same as those obtained when the fused nickel sulphide was leached under identical conditions.

The matte contained 54 percent. nickel, 24 percent. copper, and 16.5 percent. sulphur. With acid, diluted to contain more than 1 c.c. concentrated sulphuric acid per 100 c.c. of water, and when the digestion was conducted for periods of from 10 to 30 min., at boiling, the amount of nickel taken into solution was from 8 to 20 percent. of the nickel in the matte. When 150 c.c. of acid solution, containing 0.5 c.c. of concentrated sulphuric acid per 100 c.c. of water, was used, and the digestion was carried on at boiling for 30 min., the amount of nickel dissolved was from 5 to 8 percent. of the total nickel in the matte. In cases when the residue was again leached with the same strength of acid, only a trace of nickel was taken into solution. The conclusions which were deduced from these tests are the following:

(*a*) The amount of nickel sulphide dissolved in a given time by dilute sulphuric acid is roughly proportional to the strength of acid used for the digestion, and to the temperature of the solution.

(*b*) A dilute solution of sulphuric acid, containing 0.5 percent by volume of concentrated sulphuric acid, may be used for an approximate separation of copper oxide and nickel oxide from copper sulphide and nickel sulphide, by digesting the mixture at temperature between 80 and 95°C. for a period of 15 to 20 minutes.

Precipitation of Copper.— In the course of the methods generally used for the analysis of materials containing copper, the precipitation of the copper is accomplished by means of either hydrogen sulphide or metallic aluminium. The former reagent has many objections, the principal ones of which are its offensive odor, the time required to get complete precipitation, and the liability of oxidation of copper sulphide to soluble copper sulphate by air contact during washing on the filter. As no comparative results were found in the literature, the two methods of precipitation of copper were compared. A standard solution of copper sulphate was prepared so as to contain 0.2 gram of copper per 100 c.c., and the analyses were conducted as follows.

In the case of the hydrogen sulphide precipitation, 100 c.c. of the solution was diluted to about 250 c.c.; 8 c.c. of concentrated sulphuric acid was added, and hydrogen sulphide passed through for 30 min. The solution was filtered, and the precipitate of copper sulphide washed quickly with hydrogen sulphide water, preventing

as much as possible the exposure of the precipitate to the atmosphere. The precipitate, together with the filter paper, was digested with boiling dilute nitric acid. The solution was diluted to about 150 c.c., made alkaline with ammonia, about 5 c.c. added in excess, cooled, and titrated with standard potassium cyanide solution.

In cases when the copper was precipitated with metallic aluminium, 100 c.c. of the standard copper solution was diluted to 200 c.c., and 6 c.c. of concentrated sulphuric acid added. A strip of metallic aluminium, size about 1½x1¾ in., was placed in the solution, which was then boiled for 25 min. The precipitated metallic copper was allowed to settle, and the clear supernatural solution carefully decanted. The precipitate and the strip of aluminium were carefully washed twice by decantation, and then digested with dilute nitric acid (1:1). The strip of aluminium was washed and removed from the beaker; the solution diluted to about 150 c.c., made alkaline with ammonia, 5 c.c. added in excess, cooled and titrated with standard potassium cyanide solution.

The results of the tests are given in Table I, the figures representing the ratio between copper determined by titration to that present in original solution.

TABLE I. PRECIPITATION OF COPPER BY HYDROGEN SULPHIDE, AND BY ALUMINIUM.

Precipitant.	Test 1	Test 2	Test 3	Test 4	Test 5	Test 6	Average.
Hydrogen sulphide.	96.2	98.0	97.8	100.3	100.4	99.5	98.7
Aluminium.....	98.2	98.9	98.1	99.6	98.5	99.9	98.9

Finding that the precipitation of copper by aluminium gave as accurate results as when made by means of hydrogen sulphide, the next tests were conducted in order to ascertain the conditions which are necessary to separate copper quantitatively from nickel in sulphate solution by the use of metallic aluminium. Two standard solutions were prepared, one to contain approximately 0.2 gram of copper, and the other approximately 0.1 gram of nickel per 100 c.c. Samples of the solution, containing a known amount of copper and nickel, were diluted to about 200 c.c., 6 c.c. of concentrated sulphuric acid added, and the copper precipitate by boiling with a strip

of aluminium in the same manner as outlined above. The results of the precipitations and the analyses are given in Table II.

TABLE II. SEPARATION OF COPPER AND NICKEL BY ALUMINIUM.

Copper present. Gram.	Nickel present. Gram.	Time of boiling. Minutes.	Copper by titration. Gram.	Percent. error.	Nickel by titration. Gram.	Percent. error.	Remarks.
0.2005	0.0949	20	0.2004	+0.0	0.0916	—3.4	Boiled gently.
0.2005	0.0949	20	0.2047	+2.0	0.0900	—5.2	" "
0.2005	0.0949	25	0.2012	+0.3	0.0926	—2.4	" "
0.2005	0.0949	25	0.2033	+1.3	0.0920	—3.0	" "
0.1840	0.0949	25	0.1869	+1.6	0.0925	—2.5	" "
0.1840	0.0949	30	0.1876	+2.0	0.0936	—1.4	" "
0.2005	0.0949	30	0.2032	+1.3	0.0931	—1.9	" "
0.2005	0.0949	30	0.2021	+0.8	0.0914	—3.5	" "
0.0920	0.0949	25	0.0909	+1.2	0.0943	—0.7	Boiled vigorously.
0.0920	0.0949	25	0.0921	0.0	0.0950	0.0	" "
0.1504	0.0712	25	0.1509	+0.3	0.0711	—0.0	" "
0.9200	0.0949	30	0.0916	—0.4	0.0944	—0.6	" "
0.9200	0.0949	30	0.0911	—1.0	0.0954	+0.6	" "

The conditions that were found necessary in order to obtain a quantitative separation of copper from nickel by means of metallic aluminium in sulphate solution, are the presence of 3 c.c. concentrated sulphuric acid per 100 c.c. solution, boiling vigorously for 20 to 30 min., and the addition of water at intervals to replace that which is expelled by evaporation. By vigorously boiling the solution during the precipitation of the copper, the precipitate is freed from the aluminium, and nickel is held in solution. The finely divided precipitate of metallic copper settles rapidly, and the supernatant solution can be readily decanted and a good separation of nickel from copper obtained with at least two washings by decantation. Solutions containing more than about 3 c.c. concentrated sulphuric acid per 100 c.c. volume, caused the aluminium to dissolve too rapidly, which interfered later when the nickel was determined by titration. With less than this amount of acid in the solution, the copper tended to deposit slowly and to carry some nickel with it.

Determination of Copper.— The cyanide method that was used for determining copper is given in Ricketts and Miller's "Notes on Assaying" (1897 Ed.) p. 164; Sutton's "Volumetric Analysis"

(1904 Ed.) p. 190; SCHOOL OF MINES QUARTERLY, XXXII (1911) p. 380; and Low's "Technical Methods of Ore Analysis" (1908 Ed.) p. 90. The method in brief is: The solution containing copper as sulphate or as nitrate is made alkaline with ammonia, and 2 to 5 c.c. in excess. It is cooled, diluted to about 250 c.c., and titrated with a standard solution containing 22 grams of potassium cyanide per liter. The end-point is the moment of disappearance of the blue color of the copper-ammonium solution.

Determination of Nickel.—The method used for titrating the nickel solutions is described in Sutton's "Volumetric Analysis" (1904 Ed.), p. 251; Low "Technical Methods of Ore Analysis" (1908 Ed.), p. 324; Johnson "Chemical Analysis of Special Steel" (1909 Ed.), p. 104; SCHOOL OF MINES QUARTERLY, XXXII (1911), p. 381. Two standard solutions are required for the determination of nickel by this method: A solution containing 22 grams of potassium cyanide per liter, and another containing 2.0 grams of silver nitrate per liter. These two solutions are accurately standardized, and also their values with relation to each other are accurately established by titration. The value of the potassium cyanide solution in terms of metallic silver, multiplied by 0.27193, gives the standard in terms of metallic nickel (2 Ag equivalent to 1 Ni). The conditions which are necessary for the accurate determination of nickel in the presence of aluminium and iron are: The solution containing about 0.1 gram of nickel, either as sulphate, nitrate, or chloride, must contain 5 to 10 grams of tartaric, or citric acid, and enough free inorganic acid to prevent the precipitation of nickel, aluminium, and iron hydroxides when ammonia is added to slightly alkaline reaction. If a precipitate should form, then add a small amount of ammonium chloride, which should give a clear solution. Dilute to 200 c.c., add 1 c.c. of a 10-percent. potassium iodide solution (for the indicator), cool to room temperature, and run in exactly 1.0, 2.0, or 3.0 c.c. of the standard silver nitrate solution, which will produce permanent yellow opalescence. Titrate with the standard potassium cyanide solution till the moment the solution becomes permanently clear; bring back to permanent opalescence by slowly adding the silver nitrate solution drop by drop, and with constant stirring. The respective volumes of the two standard solutions are noted, the potassium cyanide equivalent of the stand-

ard silver nitrate solution is subtracted from that of the standard potassium cyanide solution, and the difference is multiplied by the nickel equivalent, which gives the amount of nickel in the titrated solution. The precautions to observe are that the solution of nickel does not contain too much ammonia, and that the titration be made with the solution at about 20°C.

Analysis of Materials containing Copper Sulphate, Nickel Sulphate, Copper Oxide, Nickel Oxide, Copper Sulphide, and Nickel Sulphide.— A one-gram sample, ground to pass through a 100-mesh screen, was digested with 150 c.c. of boiling water for half an hour, which dissolved the sulphates of copper and nickel. The solution was carefully decanted from the residue, which was twice washed by decantation with water and the washings added to the main solution. The nickel and copper were separated by adding 3 c.c. concentrated sulphuric acid per 100 c.c. solution, and boiling for about 25 minutes with a sheet of metallic aluminium, as outlined on page 8. The copper and nickel were then determined by titration by the methods described above.

The residue, containing the oxides and sulphides of copper and nickel, was digested at temperature just below boiling for about 25 min. with 150 c.c. of a 0.5 percent. (by volume) sulphuric acid solution, as outlined previously. The volume of solution was kept at about 150 c.c. by adding water several times to replace that lost by evaporation. The solution was decanted and the residue washed by decantation as described above. The copper and nickel were then separated by means of metallic aluminium, and each determined by titration, as previously outlined.

The residue, containing the copper and nickel as sulphides and as metal, was treated with about 20 c.c. of concentrated nitric acid and 2 grams of potassium chlorate, at boiling, for about 15 min. The solution was allowed to cool, 8 c.c. of concentrated sulphuric acid added, and evaporated to fumes of sulphuric acid. The casserole was allowed to cool, 200 c.c. of water added, and the copper and nickel separated, and each determined by titration, as above.

Determination of Sulphide Sulphur.— A one-gram sample, ground to pass through a 100-mesh sieve, was leached with boiling water to remove the sulphates. The residue was washed by decantation, then digested at temperature not over 85°C. with 15 c.c. of

concentrated nitric acid saturated with dry crystals of potassium chlorate, until all of the sulphur was dissolved. (If the digestion of metal sulphides is made at boiling, part of the sulphur will separate as small globules, which can be gotten into solution only with difficulty.) The solution was evaporated to dryness on a water-bath, 5 c.c. of concentrated hydrochloric acid added, and again taken to dryness. The dry mass of salts was then taken up with 5 c.c. of concentrated hydrochloric acid and 15 c.c. of water, and heated to boiling, after which the residue was filtered off and washed with hot water. The filtrate was brought to boiling, and the sulphate precipitated by adding barium chloride. The barium sulphate was filtered, washed with hot water, dried, ignited at red heat, and weighed. The weight of the precipitate multiplied by 0.1373 gave the sulphur equivalent.

II. Determination of the Reaction between Copper Oxide and Nickel Sulphide.

A mixture of pulverized commercial copper oxide (CuO) and pulverized nickel sulphide (Ni_5S_4) was made to contain an equivalent molecular proportion of each. Five grams of the mixture was placed in a porcelain crucible, and heated in an electric resistance furnace at definite temperatures. Three runs were made for periods of two hours; one at temperature between 500° and 525°C., a second between 600° and 650°C., and the third between 700° and 750°C. The product of each run was analyzed for copper and nickel as sulphates, oxides, and sulphides. The results are given in Table III. They indicate: First, that at some temperature between 525° and 600°C. the sulphates of copper and nickel begin to form, when a mixture of nickel sulphide (Ni_5S_4) and copper oxide is heated, the nickel sulphate forming in larger proportion than copper sulphate; second, the heating of a mixture of nickel sulphide (Ni_5S_4) and copper oxide at temperatures above 725°C. is not conducive to the formation of sulphates, but does cause the mutual interaction of nickel sulphide and copper oxide, forming copper sulphide and nickel subsulphide; third, when mixtures of nickel sulphide and copper oxide are heated between 500°C. and 650°C., there is a slight interchange of sulphur and oxygen between the copper oxide and the nickel sulphide; fourth, at temperatures above

700°C. the mutual reaction between nickel sulphide and copper oxide is the more rapid the higher the temperature; fifth, when copper oxide is heated above 600°C. with nickel sulphide, which contains sulphur in excess of that indicated by nickel subsulphide (Ni_2S), copper sulphide is produced as the result of the reduction of the higher sulphide of nickel to the subsulphide, as indicated by the following equations.

Temperature between 500° and 650°C. —

$$4CuO + 5NiS = 2Cu_2S + 2Ni_2S + NiSO_4$$
$$5CuO + 5NiS = 2Cu_2S + 2Ni_2S + CuSO_4 + NiO$$
$$6CuO + 8NiS + O_2 = 2Cu_2S + 4Ni_2S + 2CuSO_4$$
$$3CuO + Ni_3S_4 + O_2 = Cu_2S + 2Ni_2S + CuSO_4 + NiO$$

Temperature between 700° and 750°C.—

$$2CuO + 4NiS = Cu_2S + 2Ni_2S + SO_2$$
$$4CuO + 5NiS = 2Cu_2S + 2Ni_2S + NiO + SO_3$$
$$6CuO + 4Ni_3S_4 = 3Cu_2S + 10Ni_2S + 3SO_2$$

As the temperature of decomposition of copper sulphate is 640°C., and that of nickel sulphate is 730°C., these sulphates do not form when a mixture of copper oxide and nickel sulphide is heated at temperatures above 730°C.

These reactions indicate that nickel subsulphide is a very stable compound, and also that when mixtures of copper oxide and nickel sulphide are heated at temperatures below 750°C., they do not mutually react according to the equations:

$$4CuO + 4NiS = 2Cu_2S + Ni_2S + 2NiO + SO_2.$$
$$2CuO + Ni_2S = Cu_2S + 2NiO.$$
$$6CuO + 4NiS = 3Cu_2S + 4NiO + SO_2.$$

TABLE III. REACTION OF COPPER OXIDE AND NICKEL SULPHIDE

Temperature of Reaction. Deg. C.	Proportion of Copper as			Proportion of Nickel as		
	Sulphate.	Oxide.	Sulphide.	Sulphate.	Oxide.	Sulphide.
Before heating.....	0.0%	92.5%	7.5%	0.0%	5.8%	94.2%
500° to 525°.....	0.0	87.0	13.0	0.0	7.3	92.7
600° to 650°.....	9.5	83.0	7.5	13.0	4.0	83.0
700° to 750°.....	6.0	65.0	29.0	7.0	6.0	87.0

The results of these experiments, together with the facts that during the converting of a copper-nickel matte the nickel does not enter the slag but is simultaneously reduced with the copper, producing an alloy, indicate that at high temperature nickel subsulphide (Ni_2S) is the stable sulphide, and also that nickel subsulphide acts similarly to cuprous sulphide when both are associated and are subjected to high temperatures.

III. ROASTING OF A COMMERCIAL COPPER-NICKEL MATTE.

The matte, which was roasted, was furnished by the Orford Copper Company. It was ground and screened; that which passed through a 30-mesh and remained on a 40-mesh screen was retained

FIG. 1. MAG. 30 DIAM.

FIG. 2. MAG. 175 DIAM.

PHOTOMICROGRAPHS OF COPPER-NICKEL MATTE.

for one series of roasts, and that which passed through 60-mesh and remained on an 80-mesh screen was retained for a second series of roasts. A sample from each lot was analyzed and found to contain 54 percent. nickel, 24 percent. copper, and 16.5 percent. sulphur.

A small piece of the matte was polished on one face, etched with a dilute (1:4) solution of hydrochloric acid. The etching served as a means of distinguishing the several constituents of the matte by taking advantage of their different solubility in the dilute acid: the excess of nickel subsulphide was slowly dissolved and assumed a dark-brown color after five to six minutes' treatment; whereas the eutectic of nickel subsulphide and cuprous sulphide was not appreciably attacked but remained as irregular, bright masses of light bluish tinge; and the alloy of nickel-copper which was not attacked

by the acid appeared as small, bright-yellowish masses having more or less square corners and surrounded by the sulphides. The specimens, after etching, were washed first with water, then with alcohol, and dried.

The microphotographs, Fig. 1, magnification 30 diam., and Fig. 2, magnified 175 diam., show in eutectic of nickel subsulphide and cuprous sulphide as the light irregular mass which surrounds the excess of nickel subsulphide, and the alloy of nickel and copper saturated with sulphide. The black spots are cavities in the matte, the dark irregular masses are the excess of nickel subsulphide, and the darker masses which have more or less square cor-

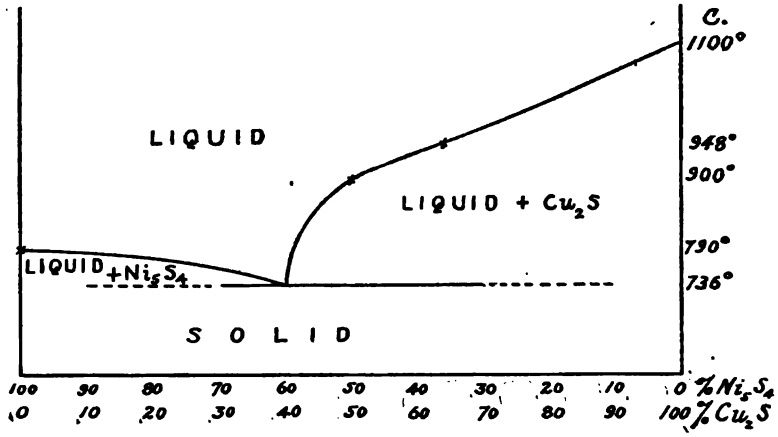


FIG. 3. THERMAL DIAGRAM COPPER-NICKEL SULPHIDES.

ners are crystals of the alloy of nickel and copper saturated with sulphide.

The thermal diagram of nickel sulphide (Ni_5S_4) and cuprous sulphide, Fig. 3, which was constructed by using the cooling curves of Walters (SCHOOL OF MINES QUARTERLY, XXXII, 376) illustrates what occurs when a mixture of nickel sulphide and copper sulphide is allowed to cool slowly from the molten to the solid state. When a mixture containing more than 40 percent. of cuprous sulphide is cooled from the molten to the solid condition, the excess of cuprous sulphide (above 40 percent.) crystallizes until the mother liquid reaches the eutectic composition, when the remaining liquid mass solidifies as the eutectic. A micrograph of such a solidified mixture will show the crystals of cuprous sulphide in a ground-mass of

the cuprous-nickel sulphide eutectic. In the case of mixtures containing more than 60 percent. of nickel sulphide, when they are cooled from the molten condition, the excess of nickel sulphide will crystallize first, and when the concentration reaches 60 percent. of nickel sulphide the mother liquor will solidify as the eutectic. A micrograph of such a solidified mixture will show the excess of nickel sulphide as crystals and the sulphide eutectic as a ground mass.

The micrographs, Fig. 1 and Fig. 2, show what occurred when a mixture containing about 55 percent. of nickel sulphide (Ni_2S), 23 percent. cuprous sulphide, 11 percent. metallic nickel and 5 percent.

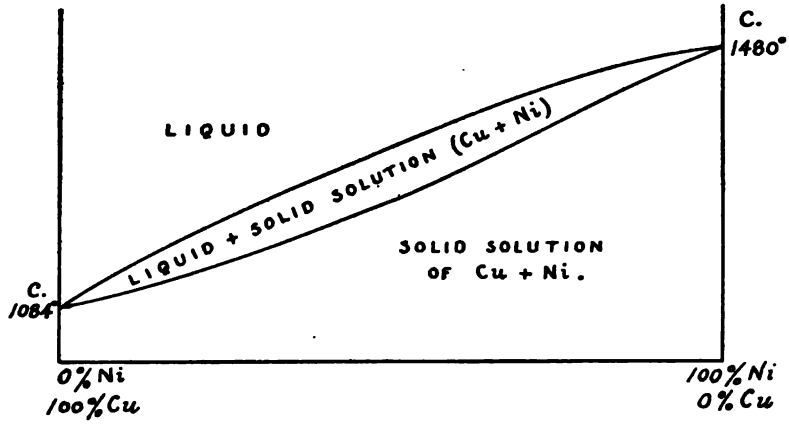


FIG. 4. THERMAL DIAGRAM COPPER-NICKEL ALLOYS.

metallic copper was slowly cooled from the molten state. The alloy of nickel and copper (in the proportion of 11 parts nickel and 5 parts of copper, or 69 percent. nickel and 31 percent. copper), which has a freezing point about 1350°C., as shown by the thermal diagram, Fig. 4, was the first constituent to crystallize from the molten matte during its cooling. When the temperature reached 790°C. nickel subsulphide began to separate from the fused mass and continued to do so until the composition of the liquid approximated six parts of nickel sulphide and four parts of cuprous sulphide, which, being the eutectic, solidified completely at about 735°C. The calculated composition of the matte is 55 percent. nickel subsulphide (Ni_2S), 23 percent. cuprous sulphide (Cu_2S), 11 percent. nickel, and 5 percent. copper, these

latter two as an alloy. The constituents of the matte, as calculated and confirmed by the relative areas occupied by the constituents as shown by the microphotographs, are approximately 16 percent. nickel-copper alloy (69 parts of nickel and 31 parts of copper), 20 percent. nickel subsulphide (Ni_2S), and 58 percent. eutectic of nickel sulphide and copper sulphide, which corresponds to the formula ($5Ni_2S.\ 3Cu_2S$), the composition of which is 61 percent. Ni_2S and 39 percent. Cu_2S.

Knowing the condition in which the copper and nickel existed in the raw matte, the reactions and the manner in which they occurred could be more readily interpreted. The roasting experiments were conducted with about 300 grams of the crushed and uniformly sized matte, one lot being between 30 and 40 mesh and the second lot between 60 and 80 mesh. The roasting was done in large fire-clay roasting dishes, the thickness of the layer of matte being about ½ in. The two dishes, containing the respectively sized matte, were placed side by side in a gas-fired muffle furnace, and the roasting was carried on in each case under conditions as nearly identical as possible, with respect to temperature, air supply, and rabbling. The temperatures were determined by means of a LeChatelier thermo-couple, which was placed between the roasting dishes, readings being taken at intervals of 15 min. At definite intervals during the roasting, samples of the matte were dipped from the dishes, by means of a long-handled iron spoon; they were pulverized to pass through a 100-mesh screen, and analyses were made for nickel and copper as sulphate, oxide, and as sulphide and alloy. The sulphur content was determined on a separate sample. The methods of analyses are described in the latter paragraphs of Part I.

Three runs were made: Roast No. I at a temperature between 475° and 500°C. for a period of nine hours; Roast No. II at a temperature of 575° to 600°C. for a period of nine hours; and Roast No. III at a temperature of 675° to 720°C. for a period of six hours. It was found in each case that fritting of the matte particles started when the temperature of the furnace reached about 450°C. In order to prevent caking of the matte particles, a preliminary roasting was made at about 450°C. for one hour, and the material frequently rabbled by means of an iron rake. It was more difficult to prevent the finer material from fritting and caking than the coarser material. After the particles had become coated with

a thin layer of oxide, the temperature of the furnace could then be raised without danger of fritting the matte particles. After the preliminary roasting, the temperatures were in each case raised to, and maintained at, the degree stated above, and held there for the definite periods.

The data obtained by the roasting experiments are given in Tables IV, V, VI, VII, VIII, and IX. In the case of Roasts IIIa and IIIb, which were carried on between 675° and 720°C., and when it was desired to obtain complete elimination of the sulphur, a test to determine the presence of sulphide sulphur was made by mixing a small amount of the roasted matte with about an equal weight of pulverized potassium chlorate ($KClO_3$) and heating to redness in a small porcelain crucible in the flame of a Bunsen burner. If sulphide sulphur is present, the mixture will react violently; if the mixture fuses with no apparent reaction, the roasting has been carried to completion.

The results of these roasting experiments show that the oxidation of nickel-copper matte takes place slowly at temperatures below 625°C., whereas between 675° and 725°C. the elimination of sulphur by roasting is rapid. When the temperature is allowed to exceed 735°C., which is the freezing point of the eutectic of nickel sulphide and cuprous sulphide, the particles of matte cement together, which prevents the air from readily getting in contact; consequently oxidation is retarded. Sintering of the matte particles during roasting may be prevented by maintaining the temperature at the start between 450° and 500°C. for about an hour, in order that the particles may become thoroughly coated with a layer of oxide, after which the temperature may be raised to between 675° and 725°C.

Referring to Tables VIII and IX, it is seen that the desulphurization at the end of one hour's roasting at an average temperature of 650°C. was 45 percent. in the case of matte particles which were between 60 and 80 mesh, and about 22 percent. in the case of matte particles which were between 30 and 40 mesh. The percentage desulphurization at the end of three hours, when the average temperature was 690°C., was 94.5 percent. and in the case of the finer material, and 91 percent. in the case of the coarser. Comparing these results with those recorded in Tables IV, V, VI, and VII, it is seen that the percentage desulphurization during nine hours at

TABLE IV. Roast No. Ia. Roasted for 9 hours at 475° to 500° C. Matte particles 60 to 80 mesh.

Sample No.	Time of Roasting Hours.	Average Temperature. Deg. C.	Percentage of Total Nickel as:			Percentage of Total Copper as:			Percentage of Sulphide Sulphur.	Percentage Desulphurization
			Sulphate.	Oxide.	Sulphide and Alloy.	Sulphate.	Oxide.	Sulphide and Alloy.		
1	1	460	0	11.3	88.7	0	1.8	98.2	15.1	8.0
2	3	495	0	10.5	89.5	0	7.4	92.6	14.4	12.7
3	5	495	0	9.4	90.6	0	7.9	92.1	14.2	14.0
4	7	490	0	9.2	90.8	0	10.2	89.8	14.1	14.6
5	9	490	0	8.8	91.2	0	10.7	89.3	14.0	15.2

TABLE V. Roast No. Ib. Roasted for 9 hours at 475° to 500° C. Matte particles 30 to 40 mesh.

1	1	460	0	13.5	86.5	0	1.2	98.8	15.7	4.9
2	3	495	0	11.8	88.2	0	1.7	98.3	15.5	6.0
3	5	495	0	10.0	90.0	0	2.5	97.5	15.4	6.7
4	7	490	0	7.1	92.9	0	4.4	95.6	15.3	7.3
5	9	490	0	7.2	92.8	0	5.3	94.7	15.2	8.0

TABLE VI. Roast No. IIa. Roasted for 9 hours at 575° to 600° C. Matte Particles 60 to 80 mesh.

1	1	595	0.4	8.5	91.1	0.5	16.4	83.1	12.3	25.4
2	3	593	4.2	6.8	89.0	2.9	19.0	78.1	12.0	27.3
3	5	582	7.0	8.7	84.3	2.6	23.3	74.1	11.6	29.7
4	7	586	8.9	8.7	82.4	3.3	25.1	71.7	11.2	32.1
5	9	589	6.3	12.7	81.0	4.0	27.2	68.8	10.4	37.0

TABLE VII. Roast No. IIb. Roasted for 9 hours at 575° to 600° C. Matte particles 30 to 40 mesh.

Sample No.	Time of Roasting Hours.	Average Temperature Deg. C.	Percentage of Total Nickel as:			Percentage of Total Copper as:			Percentage of Sulphide Sulphur.	Percentage Desulphurization.
			Sulphate.	Oxide.	Sulphide and Alloy.	Sulphate.	Oxide.	Sulphide and Alloy.		
1	1	595	0	5.6	94.4	0	2.5	97.5	14.9	9.7
2	3	593	0	7.7	92.3	0	5.7	94.3	14.7	10.9
3	5	582	0.1	9.8	90.0	0.3	10.4	89.3	13.9	15.7
4	7	586	0.4	10.0	89.6	0.8	7.7	91.5	13.7	17.0
5	9	589	0.8	15.4	83.8	1.5	6.0	92.5	13.4	19.0

TABLE VIII. Roast IIIa. Roasted for 6 hours at 675 to 720° C. Matte particles 60 to 80 mesh.

1	1	605	0	9.7	90.3	0	6.8	93.2	9.0	45.4
2	3	690	0	5.6	94.4	0	55.5	44.5	0.9	94.5
3	5	712	0.2	3.9	95.9	1.1	60.0	38.9	0.3	98.2
4	6	696	0.3	4.1	95.6	1.1	59.5	39.4	0.2	98.8

TABLE IX. Roast IIIb. Roasted for 6 hours at 675 to 720° C. Matte particles 30 to 40 mesh.

1	1	605	0	10.6	89.4	0	2.8	97.2	12.9	21.8
2	3	690	0	3.1	96.9	0	49.7	50.3	1.5	91.0
3	5	712	0	3.7	96.3	0	59.9	40.1	0.4	97.5
4	6	696	0	3.7	96.3	0	61.0	39.0	0.25	98.5

temperatures between 460° and 500°C., and between 575° and 600°C., was not in any case so great as that which took place during one hour's roasting at 650°C.

These roasting experiments indicate that at temperatures between 650° and 725°C. an oxide of nickel is formed which is not soluble in dilute sulphuric acid (100 c.c. water and 0.5 c.c of conc. acid). This is also indicated by the results in Table III. In Tables VIII and IX, in the column headed "Percentage of Total Nickel as Oxide" the amount of nickel oxide determined in the roasted matte was less with increase in time of roasting, which cannot actually be true. As the desulphurization at the end of three hours was over 90 percent., and the amount of nickel oxide determined was less than 6 percent., an explanation for the small amount of oxide of nickel and the decrease in amount with continued roasting, is that the oxide which forms at temperatures between 650° and 725°C. is insoluble in the dilute acid which was used to separate the oxide from the sulphide and the alloy. In the case of the copper oxide there was an increase with extension in time of roasting.

CONCLUSIONS.

A summary of the results of the experiments is as follows:

In the analysis of copper-nickel materials, the copper may be separated from the nickel by getting them into solution as sulphates and boiling the solution with a strip of metallic aluminium, in the presence of about 3 c.c. of concentrated sulphuric acid per 100 c.c. volume.

When a mixture of nickel sulphide and copper oxide is heated, a small amount of copper sulphate and nickel sulphate are formed when the temperature is maintained between 525° and 600°C. Above 650°C. these sulphates do not form, but there is a mutual interaction of the nickel sulphide and the copper oxide, with the formation of cuprous sulphide and mixed subsulphide; the higher the temperature the more rapid the formation of the cuprous sulphide. The results also indicate that nickel subsulphide is a very stable compound; and that when a mixture of nickel subsulphide and copper oxide are heated, no apparent reaction takes place.

The roasting of nickel copper matte proceeds slowly at tempera-

tures below 600°C. At temperatures above 730°C. the matte particles become pasty and cake into masses which prevent rapid oxidation. The most rapid and most complete roasting of nickel-copper matte may be obtained by first roasting for about an hour at 450° to 500°C., with free access of air, in order to coat the matte particles with a thin layer of oxide, after which the temperature may be raised to between 675° and 725°C. Vigorous rabbling during the roasting is necessary to prevent fritting of the matte particles. Obviously, the finer the matte particles the more rapidly the roasting may be accomplished.

PETROGRAPHIC RANGE OF ROAD-BUILDING MATERIALS.

BY CHARLES P. BERKEY.

It frequently falls to the lot of a petrographer to classify stone which it is proposed to furnish for a special piece of work, and to give an opinion as to its fitness or its likelihood of meeting the requirements of specifications. In most cases these requirements are very far from being specific, in a petrographic sense, i. e., precise rock names are rarely used, whereas some general term or some phrase descriptive of the quality is common. The commonest term of all is "trap."

A few quotations copied from standard specifications covering regular contracts under various state and municipal departments, and bureaus of highways, are given below as representative of this usage:

(a) "Only broken stone . . . of a hard and compact texture and of uniform grain will be allowed . . . Disintegrated and rotten stone . . . will not be accepted."

(b) "The trap rock shall be of satisfactory quality, equal to that used in . . . for macadam roads."

(c) "The mineral aggregate used shall consist of trap rock, newly broken, of uniform quality throughout, free from slaty and flat pieces, soft or disintegrated stone, dirt and other objectionable material."

(d) "The stone . . . must be trap or approved native rock. It must show a fresh crystalline surface."

(e) "All stone must be . . . the same kind and quality, equally good in every particular as that shown in the Engineer's office."

(f) "Only good, solid stone shall be used . . . Bidders will name the kind of stone they propose using in said work, also its location."

(g) " . . . shall consist of first quality trap rock . . . Mineral aggregate shall be clean crushed trap rock of approved quality."

(h) "Crushed stone shall have a coefficient of wear, according to the Duval test, of not less than 8, and a cementation value of not less than 50."

(i) "The first course shall consist of sound rock . . . Unless otherwise specified, the stone of the second course shall be trap rock . . . For the third course other material than trap rock screenings may be used if approved by the Engineer."

(j) "Stone for macadam shall consist of approved local stone, trap rock, or a combination of local stone and trap rock . . ."

(k) "The crushed stone shall be trap or other suitable rock, satisfactory to the office in charge."

(l) "The macadam shall be of limestone of approved quality . . . The stone must be of good and uniform texture."

(m) "All stone for concrete shall be hard limestone, sandstone, trap, furnace slag, quartzite, or granite, acceptable to the Chief Engineer. Broken stone must be quarried from massive ledge, and any stone which shows a tendency to break into flat, thin pieces will be rejected."

(n) "The broken stone shall be trap, granite, or limestone, or such other stone taken from the line of work as shall be satisfactory in the judgment of the Engineer."

Such a summary is probably fairly typical. From it two or three generalizations may be made. For example: (1) The standard, so far as there is a standard, with which all rocks are compared in highway work, is "trap." (2) Trap is usually specified by name wherever there is any reasonable hope of furnishing it for the contract. (3) Wherever substitutes are encouraged they are either indicated by name, or are described in efficiency terms, or the responsibility is placed directly on the engineer in charge.

It is the general opinion, based on experience, that the "traps" are pre-eminently satisfactory for highway uses. But trap is not a very definite petrographic term. In a very broad way this means that the basic igneous rocks of massive structure, and having a tendency to diabasic or closely interlocked habit of the mineral constituents, are the best road material. The acid igneous rocks are not so successful, especially when there is heavy traffic sufficient to test the toughness of the rock. The metamorphic rocks, as a class, are not regarded with much favor. The clastic or fragmental rocks, as a rule, are not recommended, but limestones are very serviceable where hardness is not a prime essential. In every large class of rocks there are special types which prove to be of acceptable grade, but no large class compares with the basic igneous rocks for general efficiency under the most exacting conditions.

In spite of this apparent reduction to such simple terms in the matter of range of rock types regarded as acceptable, as a matter of fact, a great variety of rocks are actually used and are quite worthy of serious consideration. Many factors enter into the question of choice; it is not always a simple problem. There is little excuse for a state like Ohio to demand trap in any except the most critical cases, for there is not a single trap ledge in the state or anywhere near its borders. It may well happen, in many cases, that the increased efficiency is more than counterbalanced by the extra cost over local stone. In the average case, local stones everywhere merit serious consideration, and a little judicious discrimination will usually discover an acceptable one.

It is in this connection that critical knowledge of rock variation will be found useful. Names of rocks alone are not so useful as might at first appear, because all types vary greatly in minor points of texture, structure, chemical, and dynamic modification, and con-

sequent efficiency. No amount of mere classification can take the place of careful discrimination of structural variety within the principal types themselves.

It may be useful, however, to consider briefly the range of types coming within observation for such uses, and to indicate their petrographic grouping. Probably no publication on rock for highway uses has given a fuller list of varieties than *Bulletin* 44 of the Office of Public Roads, U. S. Department of Agriculture, Washington.

The following list has been compiled from this and other sources, and the terms are classified under the commonly used headings familiar to all students of natural rock materials. In it there is no attempt to indicate relative value for actual use. For reasons suggested in an earlier paragraph it is certain that particular varieties of a type which is usually considered of poor quality may very well prove to be much superior to the more faulty varieties of rock types that are generally regarded as high-grade. The descriptive terms following some of the rock names indicate the varieties that have been used; the terms are inserted just as they occur in the literature, without any attempt to reduce them to uniformity.

I. Igneous Rocks:

(*a*) Volcanic fragmental materials:

1. Volcanic ash.
2. Volcanic breccias.
3. Rhyolite tuff.
4. Andesite tuff.
5. Basalt tuff.

(*b*) Surface flows (crystalline lavas, felsitic, and slightly porphyritic in texture and showing flowage structure):

6. Rhyolite and rhyolite breccia.
7. Felsite and brecciated felsite.
8. Trachyte.
9. Andesites: Augite; Hornblende; Andesite breccia.
10. Basalt: Vitreous; Olivine; Chloritized.

(*c*) Intrusive masses (dikes, sills, etc.; strongly porphyritic or intimately interlocked in texture):

11. Granite porphyry.
12. Syenite porphyry.
13. Camptonite.
14. Diabase ("trap" of highest grade): Hypersthene; Uralitic; Olivine; Augite; Gabbro; Meta-diabase.

15. Diabase porphyry.
16. Peridotite.
17. Pegmatite.

(*d*) Plutonic masses (deep-seated in origin; granitoid in texture and massive structure):

18. Granite: Hornblende; Porphyritic; Muscovite; Microgranite; Gneissoid.
19. Syenite: Augite; Quartz.
20. Granodiorite.
21. Diorite: Quartz; Augite; Basic; Porphyritic.
22. Gabbro: Hornblende; Hypersthene; Uralitic.

In the above grouping, the field relations are indicated in the subheadings, and under each the rock types of which the names have been found mentioned in road tests, or rock lists for such purpose, have been arranged approximately in order from the more acid to the more basic in composition.

II. Sedimentary (clastic) rocks and associated organic accumulations and aqueous precipitates, together with special modifications:

(*e*) Simple sediments (arranged from fine to coarse grain):

23. Shale: Clay; Ferruginous; Carbonaceous; Calcareous.
24. Sandstone: Argillaceous; Calcareous; Ferruginous; Chloritic; Feldspathic; Arkose; Kaolinized; Biotite; Indurated; Metamorphosed; Conglomeritic.
25. Conglomerate.

(*f*) Organic in origin, with or without sedimentary intermixture, and usually with some modification:

26. Limestone: Shell; Fossiliferous; Clay; Argillaceous; Bituminous; Siliceous; Nodular; Oolitic; Cherty; Dolomitic.
27. Dolomite: Argillaceous; Arenaceous; Siliceous.

(*g*) Precipitates:

28. Travertine (tufaceous limestone).
29. Gypsum.

(*h*) Special segregations, etc.:

30. Quartz.
31. Chert: Calcareous; Dolomitic.
32. Flint.
33. Hematite.
34. Phosphate rock.

III. Dynamic fragmental materials:

(*i*) 35. Breccia: Quartz; Quartzite; Brecciated felsite.

IV. Metamorphic rocks (that have been recrystallized and have lost most of their original structural habit and in part their mineralogic habit. As a rule they have a

foliate structure and break much more readily in one direction than in others):

(*j*) Fine-grained types (with good rock cleavage):

36. Slate or argillite: Clay; Siliceous; Calcareous; Indurated slate.

(*k*) Medium grained (rather massive and comparatively little foliate habit):

37. Quartzite: Calcareous; Sericitic; Feldspathic; Chloritic; Pyroxene; Epidote; Hornblende; Micaceous.
38. Graywacke.

(*l*) Strongly foliated and usually of medium grain (commonly of abnormal composition, i. e., some mineral other than feldspar in excess):

39. Schist: Quartzite; Mica; Biotite; Quartz-mica; Hornblende; Mica-hornblende; Hornblende-mica; Chlorite; Hornblende-chlorite; Garnet-hornblende; Quartz-hornblende: Tremolite; Talc schist (soapstone).

(*m*) Foliated structure, medium to coarse grain, sometimes banded and of normal composition (i. e., the usual feldspathic mineral makeup):

40. Gneiss of unstated relations: Quartz; Sericite; Hornblende; Arkose; Chlorite; Muscovite; Biotite; Pyroxene.
41. Granite gneiss.
42. Syenite gneiss.
43. Diorite gneiss.
44. Gabbro gneiss.

(*n*) Massive types:

45. Marble: Dolomite marble.
46. Serpentine: Hornblende serpentine.
47. Amphibolite.
48. Eclogite: Mica eclogite.
49. Epidosite.

This list represents in reality a very wide range. It is certain that many of them are of very low efficiency, but in spite of that they have been found worthy of consideration and test. Nos. 10, 13, 14, 15 and 21 are the prominent "trap" representatives. Diabase, No. 14, is the type usually meant when the term is used in specifications. But it is not a closely defined petrographic term and is often more loosely used.

The fact that these rock names appear as having been considered worthy of attention for road-building purposes, does not necessarily indicate special fitness of all these types. Many of them are doubtless very poor grade compared with trap, but they may in spite

of that be superior to the only other materials warranting practical comparison in a given case. Furthermore, the fact that any one of these has been used successfully cannot be taken as evidence that every occurrence of the rock of the same petrographic classification would be acceptable, since so much depends on the physical condition, freedom from decay, texture and special structural factors of each occurrence. I say nothing of other factors of control lying outside of my present line of discussion — such as availability of other competing materials, transportation difficulties, allowable cost, uses to which the road is to be put, etc.

No doubt it would be a great convenience for highway engineers if a special classification, in which the prominent efficiency factors were given chief place, could be devised. The chief difficulties with such a scheme are:

(1) That it is an attempt to simplify data that are essentially not simple.

(2) That its basis could not coincide at all with that of any other rock classification; and therefore,

(3) That the terms used in classification could not agree closely with those in common use.

The result would be, it seems to me, that we should have another classification to become familiar with, instead of accomplishing a simplification. On the whole, there is as yet no better suggestion than that the commonly used terms for description and naming should be thoroughly mastered and that the nature of the structural and textural basis of difference in quality should be fully understood, and that the geological and petrographic principles underlying the history of rocks should be a part of one's professional equipment.

A STUDY OF ORE FLOTATION.

BY DONALD G. CAMPBELL.

The object of this paper is to describe the results of a series of experiments undertaken to determine the efficacy of oil flotation in the treatment of a certain antimonial silver ore. This ore had a siliceous gangue, and the valuable mineral was in the form of stibnite and stephanite, very finely disseminated through the gangue. Flotation consists in the separation and recovery of valuable minerals from gangue by causing them to float in the form of a froth or oily scum on the surface of the pulp, and skimming this off, or causing it to flow off, for further treatment. The gangue remains behind in the pulp. This, it has been shown by different experimenters, is accomplished through the application of the following principles:

1. Certain metalliferous minerals, especially sulphides, are less easily moistened by water than is a siliceous gangue, but are more easily wet by oil; hence they tend to float on the surface of water, through the agency of surface tension alone.

2. Such a mineral adheres much more strongly to air or gas bubbles, when coated with a minute quantity of oil, and hence when agitated with air or gas is easily drawn to the surface, where it forms a more or less permanent froth.

3. Even a small amount of acid tends to cause a more selective action as between the mineral and the gangue; so that when the solution is even slightly acid, less gangue is brought to the surface, and a more pure concentrate is obtainable.

Flotation is especially applicable to ores in which it is difficult to separate the minerals from the gangue by differences in specific gravity; to those minerals which float off with the gangue, due to their friability and consequent sliming, or because of their "greasiness"; and to ores which are very finely disseminated in the gangue, and thus require fine grinding to liberate, such as many silver and disseminated copper ores.

On the other hand, flotation is more or less difficult under the following conditions (Hoover):

1. Ores which are in the form of oxides or carbonates have much less adhesive action for oil or gas than have the sulphides,

and have not been successfully treated by any of the present methods.

2. Ores which contain more than about 5 percent. of a carbonate consume acid unnecessarily, and thus add to the expense.

3. When the gangue contains an easily floatable mineral, the presence of which is objectionable or deleterious to the value of the concentrate, such as fluorite in zinc, or pyrite in various sulphides.

4. Some copper ores such as bornite and chalcocite have been found to vary widely in their adaptability to this form of treatment, sometimes making a good extraction, and other times not doing so well.

Of the several flotation processes already developed, the most recent, and apparently the most successful, is that used and licensed by the Minerals Separation, Ltd., in which has been applied the principle that a minute quantity of oil, thoroughly agitated in the pulp, with air, will form a froth to which the sulphide particles will selectively adhere, and be floated on the surface; a small amount of acid is added, to decrease the tendency of the siliceous gangue to float with the ore. This was the general method followed in the experiments which follow, the variants being the kind of oil used, the amount of acid, the duration of agitation, the speed of the agitator, and the temperature of the solution.

The stirring machine.— To stir the solutions, a small motor (Tiffnay type, variable speed) was mounted adjustably on an upright stand, with the axis of the machine vertical; it was provided with an extension shaft, on the lower end of which was a four-blade agitator. By this arrangement, the stirrer could be readily moved in and out of the solution, which was placed in a rectangular glass jar, to promote thorough stirring. The agitator was 2.75 in. diameter, and the speed of the motor was variable from 100 to 1800 r.p.m. This was sufficient to produce a violent churning of the mixture, and a thorough agitation with air. The agitator first used was shaped like a propeller, but this did not give the churning effect necessary for stirring air into the solution. The next one had the planes of the blades parallel to the axis; this gave much better results, but did not give sufficient upward effect, for concentric rings of the mineral formed on the bottom of the vessel beneath the agitator, showing that these did not get into sufficient circulation to be-

come mixed with the froth. Accordingly, the blades were slight angularity, which shape churned the pulp with the m tive results.

Test of oils.—A number of oils were taken, represen ferent types, in order to determine the one having the most enduring froth-forming characteristics. The fo tried: cylinder and machine mineral oils; sperm, fis oils; corn, cottonseed, and rapeseed oils; China-wood pine, and pine-tar oils.

A number of tests, made first in test-tubes, and la amounts in the stirring machine, showed that the fir not tend to form perceptible froths in either the pres of ore, but tended to agglomerate the sulphides into bottom of the jar. When the proportion of the greatly increased, these globules broke up and sho to rise to the surface, due apparently to the adhesi the air bubbles. In no case, however, was any decide by these mineral oils.

Of the other oils, the sperm and the China-wood froth which did not seem very permanent, especially w tion was somewhat acidified. The resin and the wha fairly good froths, but of a non-selective characte solution; that is, even with a short period of agitation, a large amount of the silica was carried up into the froth, while much of the sulphide remained behind.

The corn, cottonseed, and rapeseed oils gave better results; but the most encouraging results of all were obtained from the pine oil, and the pine-tar oil. The latter, in particular, formed a very heavy froth with an exceedingly minute proportion of oil, required a comparatively short period of stirring to form the froth, which was exceedingly tenacious, standing for weeks without disintegrating. It was accordingly judged best to limit the succeeding experiments to the use of pine-tar oil as the frothing agent.

The Ore.—The ore used for these tests was siliceous, containing pyrite, stibnite, and sulphides and antimonide of silver, totalling about 5 or 6 percent. The mineral was very finely disseminated through the gangue. In the necessarily fine grinding process, the silver minerals slimed excessively, making a high saving by gravity

concentration out of the question, but making it especially adaptable to treatment by flotation. Thus, in grinding the ore to such a size that 40 percent. of it would pass 100-mesh, it was found that this fine ore assayed 212 oz. of silver to the ton, while the 60 percent. that remained on 100-mesh assayed only 108 oz. or approximately half as much.

Varying the Acid.—With even a small amount of acid present in the pulp, the effect is to reduce the total amount of the flotation product, and especially the amount of gangue that is carried up into the froth. For instance, as the mean of several experiments, it was found that when no acid was used the amount of froth product obtained from 100 gm. of ore, with 0.10 gm. of oil and 1 min. agitation, was 67 gm., and the recovery of values was 63 percent. Under the same conditions, but with the addition of 0.40 gm. of sulphuric acid, the weight of the froth product was only 32 gm. and the recovery had diminished to 49 percent. In other words, while the weight of the total product had diminished to one-half, the efficiency of recovery had diminished by 22 percent. This tendency towards lower recovery is offset by lengthening the agitation period, and by heating the solution, as will be brought out later.

In the subsequent experiments, the amount of acid used was 0.4 gm. per 100 gm. of ore, as this seemed to give the most satisfactory results, as nearly as could be determined from the preliminary nature of the experiments.

Variation of Oil.—In this series of tests, the proportion of oil to ore was varied, the amount used under the same conditions of agitation, with 100 gm. of ore, being, 0.08, 0.16, 0.24, 0.32 gm. The recovery was 56, 63, 70, and 71 percent. respectively. With oil in excess of this amount, an excessively large amount of gangue seemed to be carried into the froth, without a notably increased extraction. These results were obtained with three 1-min. agitation periods, the froth being skimmed off after each agitation. When the length of the agitation periods was increased, the amount of oil necessary was found to be very much less.

Length of Agitation.—In this series, the length of agitation was varied from 1 to 8 min. At the lower limit, it was found that even a large proportion of oil did not result in as good an extraction as when the time was lengthened and the amount of oil was decreased.

With the maximum agitation period, it was found that a high recovery could be made, but this was at the expense of a very impure froth, as much of the gangue was carried up into it, and the reduction ratio was therefore not satisfactory. Thus, as the result of tests with 200 gm. of ore at a charge, other conditions (amount of oil and of acid) being the same:

Time of agitation.	Recovery
1 min.	59%
2 "	71%
4 "	74%
8 "	77%

With the 4-min. agitation, the total froth product was 45 to 50 percent., and with the 8-min. agitation, was 65 to 70 percent. of the total weight of the ore. It was accordingly decided that the shorter periods were the best, say around 2 min. in this case.

Speed of the Agitator.—In all of the foregoing tests, the agitator had been run at full speed, or 1600 to 1800 r.p.m. This gave a peripheral speed to the agitator blades of about 1100 to 1200 ft. per min. Several tests were now made to determine the effect of lowering this speed. As a result it was found that the recovery decreased rapidly with the decrease of speed, so that at half-speed the recovery was found to be only 46 per cent. Hence the maximum speed was judged to be the most efficient, or 1100 to 1200 ft. per minute.

Temperature of the solution.—In the preceding tests, the temperature had been that of the room, or 65° F. In the results recorded below, five tests were made at the room temperature and another set of five at about 150°, the other conditions being those found best in the different series of tests described above.

Ore, 200 gm. Oil, 0.20 gm. Length of agitation, three 2-min. periods. Acid, 80 gm.

	Recovery.	Weight of Froth.
150° F.	76%	60 gm.
65° "	71%	90 "

This showed an increased extraction of 5 percent. in favor of the hot pulp, and an equally important advantage in the greater purity of the resulting froth. The heat, combined with the effect of the acid, seems to cause the particles of silica to coagulate, and thus prevent them from being carried up into the froth to as great an extent as in cold pulp.

Even this weight of flotation product seems high; in practice, it

would be reduced by again subjecting the product to agitation, perhaps several times. The original extraction, as well as the final or total extraction, would perhaps be greatly raised by finer grinding, and would certainly be raised by the mechanical and metallurgical improvements that careful study and experimentation would suggest in a large installed plant.

TABULATION OF RESULTS.

Acid Variations.—Ore, 100 gm. Oil, 0.10 gm. Agitation period, 1 min. Speed, 1800 r.p.m. Temperature, 65° F.

Acid.	Extraction.	Wt. of Product.
.0	63%	67 gm.
.20 gm.	50	60
.40 "	51	35
.40 "	48	30
.80 "	40	26

Oil Variations.—Ore, 100 gm. Acid, 0.40 gm. Agitation period, 1 min. Speed, 1800 r.p.m. Temperature, 65° F.

Oil.	Extraction.	Wt. of Product.
0.08 gm.	56%	35 gm.
.16 "	63	36
.24 "	70	34
.24 "	68	37
.32 "	71	45
.40 "	72	56

Variation of Agitation Period.—Ore, 100 gm. Acid, 0.40 gm. Oil, 0.24 gm. Speed, 1800 r.p.m. Temperature, 65° F.

Agitation Period.	Extraction.	Wt. of Product.
1 min.	59%	31 gm.
2	71	37
4	74	46
4	72	49
8	76	68
8	79	65

Variation of Speed of Agitator.—Ore, 100 gm. Acid, 0.40 gm. Oil, 0.10 gm. Agitation period, 2 min. Temperature, 65° F.

Speed of Agitator R. P. M.	Extraction.	Wt. of Product.
1800	68%	39 gm.
1200 (about)	54	32
900 "	46	26
600 "	39	18

Variation of Temperature.—Ore, 200 gm. Acid, 0.80 gm. Oil, 0.20 gm. Speed, 1800 r.p.m. Agitation period, three 2-min. periods.

Temperature.	Extraction.	Wt. of Product.
65° F.....	72%	85 gm.
"	73	79
"	70	95
"	69	93
"	73	94
150° F.....	74	59
"	78	63
"	76	65
"	77	58
"	74	55

SUMMARY.

The results obtained in the foregoing tests lead to the following conclusions:

1. Of the oils tested, pine-tar oil is the most effective froth producer, and seems to be most efficient when used in quantities approximating 0.1 percent. of the ore.

2. Without acid, the froth produced is non-selective; that is the gangue is carried up into the froth almost impartially with the valuable mineral. As acid is added, the percentage of recovery may be diminished also, but the concentration is much more satisfactory. The amount of strong sulphuric acid that seems to produce the best results is approximately 0.4 percent. of the ore.

3. For good extraction, a rapid agitation must be obtained, a peripheral speed of 1100 to 1200 ft. per min. of the agitator blades being necessary.

4. As the temperature is increased, the extraction is also increased, and the amount of oil necessary, as well as the time of agitation, may be diminished somewhat. The amount of the gangue carried into the froth is also greatly lessened, giving a much purer concentrate.

THE RELATION OF RAINFALL TO RUN-OFF IN AMERICAN RIVERS.*

BY W. F. WHITE, JR.

The object of this paper is to assemble the available data on the rainfall and run-off in the various drainage basins of the United States, and from the results to decide whether there are any definite relations between them. In addition the various factors that influence these relations are to be considered and their character and relative importance determined.

The subject is one to which little study has been devoted, and the scarcity of written information is surprising considering the importance of the questions involved, in the development of both water power and water supply. The subject, furthermore, has a vital bearing upon the floods, which are of frequent and disastrous occurrence in some sections of our country. In the *Transactions* of the American Society of Civil Engineers [1] are several papers with lengthy discussions which afford much valuable information on the actions of several individual streams and of the proportion of run-off from their catchment basins. The United States Geological Survey has taken up the study of rain and run-off, and in one of its bulletins [2] G. W. Rafter sums up what is known of their relations. The paper forms a readily accessible and invaluable source of information on the subject. In addition, several *Water Supply Papers* on various areas have given figures for the percent. of rainfall appearing in stream flow, but have not gone more deeply into the causes of the variations for different times and streams. Each year the Survey publishes a report of stream measurements for the preceding year and these have served as the source of data on run-off in the tables which follow. The data on precipitation have been collected from the records of the United States Weather Bureau.

Sir John Murray has published an article [3] on the amount of rainfall and run-off of the large rivers of the globe, and from them has assumed the ratio of run-off to rainfall for the world. He

* A Master of Arts thesis, Columbia University, May, 1913.
[1] *Trans.* Am. Soc. Civ. Eng., Vols. 10, 27 and 28.
[2] *Water Supply Paper*, No. 80, by G. W. Rafter.
[3] *Scottish Geographical Magazine*, Vol. 3.

estimates that ratio is as 1 to 4.499, or about 22.2 percent. of the precipitation. An interesting paper[4] from a French investigator bearing more on the problems of denudation by streams, and on the chemical side, has recently appeared; with this, the list of papers on the relations of rainfall and run-off in the United States practically ends.

For the calculation of the ratios in this paper, the measurements have been taken for the years 1906 to 1910 inclusive. In this five-year period we obtain a very good average of weather conditions, especially in regard to the precipitation. Of the five, two were of rather greater rainfall than is the ordinary experience, viz. 1907 and 1909; two were of less than average rainfall, namely 1908 and 1910; and one, 1906, was of nearly average amount. These statements can be made, however, only in a general way, and the mistake must not arise of assuming that any one section of the country had precipitation of more than average amount, because the country as a whole had a year of heavy rainfall. Thus, though the year 1907 had generally a much heavier rainfall than 1908, yet locally, as in the southeastern states, the latter year records the heavier precipitation. This goes to show that the rainfall is a very uncertain quantity, and makes difficult the task of determining the amount at one point of comparison with that of some other region.

The amount of rainfall even in one place shows surprising variation from year to year. In general, the maximum annual total is from two to four times the minimum. Thus, at Orono, Me., a record for 42 years gives a minimum annual precipitation of 28.5 in. in 1895, and a maximum of 58.7 in. in 1888, or a ratio of 1 to 2.1. At Boston a record for 74 years shows extremes of 27.2 in. and 67.7 in., or a ratio of 1 to 2.5, slightly greater than at Orono. The mean annual rainfall for the whole United States amounts to 29.4 in., but, due to the extreme variability for different places and times, gives no clue to the rainfall of any particular area.

The distribution of the rainfall through the year also varies greatly in different sections of the country. The precipitation may be fairly uniform throughout the year, as in the New England states, where the mean of a period of years showed that 12.2 in. of

[4] "Ecoulement fluvial et Denudation," by H. Baulig, *Annales de Geographie*, Vol. 19.

rain fell in Spring, 11.4 in. fell in Summer, 11.7 in. fell in Autumn, and 11.7 in. fell in Winter. On the other hand, the precipitation may be nearly all crowded into one period, as is commonly the case along the Pacific Coast, where, in the Sacramento Valley, 83 per-cent. of the annual precipitation falls in the period from November to April.

When rain falls on the surface of the earth it may do one of four things: It may be evaporated directly by the sun; it may flow directly into streams or lakes; it may sink into the ground; or it may be taken up by vegetation or combine with minerals of the earth's crust. The part that is evaporated by the sun is lost, and no further consideration of it need be made. The quantity of water which finds its way directly to streams varies greatly with the time of year and the nature of the country. It is much higher in Winter, when the ground is frozen, than in Summer, when the rain has a chance to sink into the ground. This part constitutes what is known as " surface flow."

That part which sinks into the ground is by far the greatest and most important, though it, too, varies with the nature of the soil. In a sandy, porous soil the amount will be very high, while in an impervious, clay soil it will be comparatively slight. This underground water serves as a source of supply in times of drought. It may reach the surface in springs, wells, or by seepage. This last is of the greatest importance, and, when it is considerable, serves to keep the flow of the streams uniform throughout the year. When it comes to the surface it is again exposed to evaporation and is partly removed in that way. With the exception of a negligible amount which sinks into the earth and is not recovered, this water finally is returned either as stream flow or evaporation.

Of the part that is consumed by vegetation, some is lost, but a considerable proportion is returned to the atmosphere by evaporation from leaves and other surfaces. Thus a very large part, which has been estimated at over 99 percent., is ultimately delivered back in the form of stream flow and evaporation. It is with stream discharge, or the run-off from a catchment basin, that we have specially to deal. The amount of this depends primarily on the precipitation, for without this there could be no run-off; yet there are

many other factors which influence the flow, and create very complex relations.

The flow of streams has been divided into the following periods: Storage, growing, and replenishing. The storage period for the eastern United States begins about December, though it may vary from year to year and in different localities, and concludes about May. During much of this time, evaporation is slight and the demands of vegetation are small, so that a large percentage of the rainfall reaches the streams. The growing period includes approximately the months from June to August, during which time both absorption by plant life and evaporation are at a maximum. As a result, the amount of rainfall that finds its way to the streams is small, and the streams have their minimum flow unless a very rainy season upsets the customary conditions. During this period, the drain on the underground water supply is severe and the level of the ground water falls. During the replenishing period, which lasts from September to November, the flow assumes more normal conditions, and the run-off is higher than during the growing period. The ground water regains its former height, and by the beginning of the next storage period everything is in favorable condition for a large stream flow.

The method used in calculating the precipitation of each basin was to select such stations of the United States Weather Bureau as were within it, and from them to pick out a number from the different sections of the basin, which would show the average conditions. From the records of these, it was possible to arrive at an approximation of the mean annual rainfall for the basin in question. The number of stations selected necessarily varied widely with different basins. In a small basin, with comparatively uniform conditions throughout, a few stations sufficed, while in a long basin, with widely varying conditions, such as that of the Columbia River, a greater number of records was required to determine the mean precipitation.

The stream measurements are those secured by the Government at its gaging stations on the different rivers. The volume of the discharge is computed by securing a profile of the stream bed at the gaging point, and then placing on some permanent object a gage which will read the height of the water. Daily readings are taken

to ascertain the cross-section of the stream, while the speed of the current is determined with a current meter. After a number of discharges have been computed, a rating curve can be drawn which will give the discharge directly from the gage height. Where the gage is at a dam or weir, somewhat different methods are used, the flow being calculated by formula. Unfortunately, these gaging stations are rarely at the mouths of streams, and as the run-off for the entire drainage basin of the stream is not given, care must be taken to specify above what point the data apply.

Stream discharge is commonly given either as foot-seconds of flow, which is the number of cubic feet passing a given point in a second; or as the average total inches in depth of water flowing from the entire drainage surface during a stated length of time. This latter method has been followed in this paper, in order that the results may be directly comparable with the precipitation records.

Rainfall measurements are always given in inches of depth during a stated time, usually a year. Accordingly, the precipitation of an entire drainage basin is expressed in inches of depth over its area.

The sources of error in precipitation records are several. In the first place, a rain gage can cover only a few square inches of ground, and to obtain accurate results a large number of gages in the same district would be necessary, which is usually impracticable. The elevation of the gage above the ground also has an important bearing on the accuracy of the measurements. Mr. FitzGerald states [5] that he kept two similar gages, one 20 feet above the other, and found that for a period of five years the upper gage showed 10.6 percent. less precipitation than the lower one. It is thus apparent that the gages should be kept as near the ground as possible, whence records of rainfall taken on the tops of buildings are of little value.

The fact that many streams have their headwaters in the mountains adds to the difficulty of securing reliable records, as there are few stations in the mountainous regions, and these are generally confined to the valleys.

The accuracy of stream measurements depends upon the type of gage used. If at a weir or dam, reliable measurements can be ob-

[5] *Jour.* Assoc. Engineering Societies, Vol. 3, No. 10.

tained, generally within an error of five percent. At other gaging stations the results are not always so accurate, and the error may range up to 20 percent. in exceptional cases. The main cause of this trouble is the constant shifting of the bottom, which renders the cross section used in the computations inaccurate unless frequently corrected.

The data in the following tables have been compiled in this manner: Following the name of the river comes that of the gaging station above which the data are computed. In the third column is stated the area of each river basin in square miles, and in the fourth the percentage which each basin constitutes of the whole drainage district. This is done for the purpose of giving due weight to the larger streams. The fifth column records the average annual rainfall of each basin, in inches, during the five years 1906 to 1910 inclusive, except in a few cases in which the average is based on only three or four of these years. The sixth column gives the annual run-off of each basin, averaged on the same five years; the figures represent inches in depth over the area of the basin above the gaging point. The ratio in the seventh column is obtained by dividing the average run-off by the average rainfall for the five years, not by averaging the ratios of the five years. The product in the last column is computed by multiplying the percentage area of each basin by its average ratio; hence the sum of this column represents the mean run-off ratio of the district.

It has been found convenient to follow the divisions of the country made by the Geological Survey, and the streams have accordingly been grouped into the following districts: North Atlantic; South Atlantic and East Gulf of Mexico; Ohio River; St. Lawrence River; Upper Mississippi River; Hudson's Bay; Missouri River; Lower Mississippi River; Western Gulf of Mexico; Colorado River; Great Basin; Pacific Coast in California; North Pacific Coast.

NORTH ATLANTIC DRAINAGE.

River.	Above.	Area		5-Year Average			Product
		Sq. Miles	Percent.	Rainfall	Run-off	Ratio	
St. John	Fort Kent, Me.	5,280	.052	38.9	21.5	.552	.0286
Fish	Wallagrass, Me.	890	.009	37.7	21.1	.559	.0050
Aroostook	Fort Fairchild, Me.	2,230	.022	41.8	25.7	.615	.0135
St. Croix	Woodland, Me.	1,420	.014	38.7	24.4	.635	.0089
Machias	Whitneyville, Me.	465	.004	43.4	31.7	.730	.0029
West Br. Penobscot	West Enfield, Me.	6,600	.065	39.6	26.0	.658	.0429
East Br. Penobscot	Grindstone, Me.	1,100	.011	37.8	23.8	.628	.0069
Mattawamkeag	Mattawamkeag, Me.	1,500	.015	39.6	25.9	.654	.0083
Androscoggin	Rumford Falls, Me.	2,090	.021	32.9	20.1	.611	.0128
Presumptscot	Sebago Lake, Me.	420	.004	40.0	17.9	.448	.0018
Saco	West Buxton, Me.	1,550	.015	43.3	23.3	.538	.0081
Merrimac	Lawrence, Mass.	4,664	.045	32.5	16.7	.514	.0231
Connecticut	Sunderland, Mass.	7,700	.077	43.2	23.6	.546	.0421
Housatonic	Gaylordsville, Conn.	1,020	.011	42.8	22.8	.533	.0059
Hudson	Mechanicville, N. Y.	4,500	.044	42.9	22.9	.522	.0229
Mohawk	Dunsback Ferry, N. Y.	3,440	.033	39.9	25.6	.642	.0212
Kinderhook	Rossman, N. Y.	330	.003	34.7	20.2	.582	.0018
Esopus	Kingston, N. Y.	324	.003	46.7	29.1	.623	.0019
Kennebec	Waterville, Me.	4,270	.042	35.5	22.1	.623	.0262
Passaic	Chatham, N. J.	100	.001	44.2	21.8	.493	.0005
Raritan	Boundbrook, N. J.	800	.008	48.0	23.5	.489	.0039
Delaware	Riegelsville, N. J.	6,430	.064	42.1	22.3	.530	.0339
Schuylkill	Philadelphia, Pa.	1,920	.019	40.0	15.7	.392	.0078
Perkiomen	Frederick, Pa.	150	.001	43.1	20.2	.468	.0005
Susquehanna	McCall Ferry, Pa.	26,800	.266	39.1	19.2	.491	.1306
Patapsco	Woodstock, Md.	250	.002	50.3	22.8	.453	.0009
Potomac	Point-of-Rocks, Md.	9,650	.095	39.1	14.1	.361	.0343
Shenandoah	Millville, W. Va.	3,000	.030	42.4	15.5	.366	.0110
Rappahannock	Fredericksburg, Va.	1,590	.015	43.8	14.4	.328	.0050
Monocacy	Frederick, Md.	660	.006	42.9	21.9	.510	.0031
Total		101,143	.998	....	....	....	.5163

Mean Run-off = 51.6%.

SOUTH ATLANTIC AND EAST GULF OF MEXICO.

River.	Above.	Area		5-Year Average			Product
		Sq. Miles	Percent.	Rainfall	Run-off	Ratio	
James	Buchanon, Va.	2,060	.029	45.3	19.4	.428	.0124
Roanoke	Roanoke, Va.	390	.006	41.9	15.0	.358	.0022
Dan	South Boston, Va.	2,750	.039	47.7	18.2	.382	.0148
Yadkin	Salisbury, N. C.	3,400	.048	50.5	23.3	.459	.0219
Wateree	Camden, S. C.	4,500	.063	53.1	22.3	.420	.0265
Broad	Alston, S. C.	4,610	.069	53.8	22.3	.415	.0286
Savannah	Woodlawn, S. C.	6,600	.092	41.8	12.7	.518	.0478
Broad	Carlton, Ga.	760	.011	47.8	19.3	.500	.0055
Cannochee	Groveland, Ga.	960	.013	48.5	18.0	.304	.0040
Ocmulgee	Macon, Ga.	2,420	.035	50.9	25.1	.404	.0141
Oconee	Dublin, Ga.	4,180	.059	47.2	17.9	.371	.0218
Chattahoochee	West Point, Ga.	3,300	.046	50.0	19.7	.487	.0225
Flint	Albany, Ga.	5,000	.070	48.5	20.1	.378	.0265
Pea	Pera, Ala.	1,180	.017	53.2	24.4	.394	.0067
Conecuh	Beck, Ala.	1,290	.018	50.6	26.2	.414	.0075
Alabama	Selma, Ga.	15,400	.216	52.5	26.2	.458	.0993
Tombigbee	Epes, Ala.	8,830	.124	37.9	14.4	.380	.0471
Pearl	Jackson, Miss.	3,120	.043	53.8	17.2	.320	.0138
Total		70,750	.998	....	....	....	.4230

Mean Run-off = 42.3%.

OHIO RIVER DRAINAGE.

River.	Above.	Area		5-Year Average			Product
		Sq. Miles	Percent.	Rainfall	Run-off	Ratio	
Allegheny	Kittanning, Pa.	11,100	.193	41.0	23.2	.566	.1088
Kistimmitas	Avonmore, Pa.	1,750	.030	39.2	23.7	.604	.0182
Tygart	Fetterman, W. Va.	1,340	.023	38.5	23.0	.596	.0138
Youghiogheny	Confluence, Pa.	430	.007	49.8	33.9	.681	.0048
Cheat	Morgantown, W. Va.	1,380	.024	44.3	27.0	.609	.0147
Muskingum	Zanesville, O.	5,830	.099	43.7	17.7	.450	.0446
New	Radford, Va.	2,720	.048	38.9	22.5	.575	.0276
Greenbrier	Alderson, N. Va.	1,340	.024	39.6	22.1	.558	.0134
East Br. White	Shoals, Ind.	4,900	.084	29.1	13.8	.474	.0398
Tennessee	Chattanooga, Tenn.	21,400	.372	46.1	25.4	.551	.2050
Little Tennessee	M'Ghee, Tenn.	2,470	.042	56.1	37.0	.660	.0277
Elk	Elkmont, Ala.	1,700	.029	50.5	30.1	.596	.0174
Duck	Columbia, Tenn.	1,200	.022	46.1	19.0	.412	.0091
Total		57,620	.997	....	....	....	.5449

Mean Run-off = 54.5%.

GREAT LAKES AND ST. LAWRENCE RIVER.

River.	Above.	Area		5-Year Average			Product
		Sq. Miles	Percent.	Rainfall	Run-off	Ratio	
Escanaba	Escanaba, Mich.	800	.027	26.6	14.8	.557	.0150
Menominee	Kois, Mich.	3,780	.126	28.8	10.6	.368	.0464
Peshtigo	Crivitz, Wis.	670	.022	26.1	10.4	.400	.0088
Oconto	Gillet, Wis.	810	.027	25.8	9.1	.353	.0095
Wolf	Keshena, Wis.	800	.027	28.5	12.4	.435	.0118
Kalamazoo	Allegan, Mich.	1,470	.164	36.0	11.4	.387	.0635
Manistee	Sherman, Mich.	900	.030	30.4	16.5	.543	.0163
Thunder Bay	Alpena, Mich.	1,260	.043	24.1	10.5	.435	.0187
Au Sable	Bainfield, Mich.	1,420	.055	34.5	16.4	.475	.0261
Huron	Flat Rock, Mich.	1,000	.034	29.0	9.2	.317	.0109
Genesee	Rochester, N. Y.	2,360	.079	40.6	14.3	.352	.0282
Seneca	Baldswinville, N. Y.	3,100	.104	30.5	14.5	.475	.0494
Oneida	Euclid, N. Y.	1,400	.035	50.7	26.9	.531	.0292
Black	Felts Mills, N. Y.	1,850	.062	41.2	24.3	.590	.0366
Oswegatchie	Ogdensburg, N. Y.	1,580	.053	41.9	24.0	.572	.0303
Raquette	Massena Springs, N. Y.	1,170	.040	41.7	23.5	.563	.0225
Saranac	Plattsburg, N. Y.	630	.020	32.7	14.6	.446	.0090
Total		29,900	1.003	....	....	....	.4496

Mean Run-off = 45.0%.

HUDSON'S BAY DRAINAGE.

River.	Above.	Area		5-Year Average			Product
		Sq. Miles	Percent.	Rainfall	Run-off	Ratio	
Red River of North	Grand Forks, N. D.	25,000	....	16.9	1.8	.107	....

Run-off = 10.7%.

UPPER MISSISSIPPI DRAINAGE.

Mississippi	St. Paul, Minn.	35,700	.545	25.0	5.3	.212	.1155
Wisconsin	Merrill, Wis.	2,630	.040	27.1	14.4	.531	.0213
Wapsipinicon	Stone City, Ia.	1,310	.020	25.4	5.7	.224	.0045
Red Cedar	Cedar Rapids, Ia.	6,320	.097	31.4	8.6	.274	.0266
Kaskaskia	New Athens, Ill.	5,220	.080	39.6	15.0	.379	.0304
Des Moines	Keosauqua, Ia.	14,300	.218	28.3	6.6	.234	.0515
Total		65,480	1.000	....	....	....	.2498

Mean Run-off = 25.0%.

MISSOURI RIVER DRAINAGE.

Missouri	Cascade, Mont.	18,300	.090	13.1	4.9	.374	.0337
Milk	Malta, Mont.	14,000	.069	8.4	0.7	.083	.0058
Yellowstone	Glendhive, Mont.	66,100	.325	12.7	2.9	.228	.0748
Little Missouri	Medora, N. D.	5,780	.028	12.4	1.5	.115	.0032
Heart	Richardton, N. D.	1,250	.006	16.1	0.8	.050	.0003
Cannonball	Stevenson, N. D.	3,650	.019	15.5	0.8	.052	.0010
Platte	Columbus, Neb.	56,900	.280	18.7	1.1	.059	.0168
Loup	Columbus, Neb.	13,540	.066	24.2	4.4	.182	.0120
Republican	Bostwick, Neb.	23,300	.114	16.9	0.3	.018	.0021
Total		202,820	.997	....	....	....	.1497

Mean Run-off = 15.0%.

LOWER MISSISSIPPI DRAINAGE.

River.	Above.	Area		5-Year Average			Product
		Sq. Miles	Percent.	Rainfall	Run-off	Ratio	
Arkansas	Pueblo, Col.	4,600	.613	15.9	2.3	.149	.0920
Purgatory	Alfalfa, Col.	1,300	.173	14.8	1.2	.081	.0140
Tallahatchie	Batesville, Miss.	1,600	.213	42.8	17.3	.404	.0871
Total		7,500	.999	....	....	....	.1931

Mean Run-off = 19.3%.

WESTERN GULF OF MEXICO DRAINAGE.

Rio Grande	Eagle Pass, Tex.	44,000	.394	12.6	1.9	.148	.0591
Brazos	Waco, Tex.	30,800	.276	10.7	0.8	.077	.0213
Colorado	Austin, Tex.	37,000	.331	9.3	0.6	.069	.0228
Total		111,800	1.001	....	....	....	.1032

Mean Run-off = 10.3%.

COLORADO RIVER DRAINAGE.

Colorado	Yuma, Ariz.	225,000	.821	10.6	1.8	.170	.1396
Green	Greenriver, Utah	38,200	.139	14.4	3.2	.222	.0311
Salt	McDowell, Ariz.	6,260	.023	22.8	3.6	.158	.0037
Grand	Glenwood Springs, Col.	4,520	.017	21.8	10.1	.463	.0079
Total		273,980	1,000	....	....	....	.1823

Mean Run-off = 18.23%.

GREAT BASIN DRAINAGE.

River.	Above.	Area		5-Year Average			Product
		Sq. Miles	Percent.	Rainfall	Run-off	Ratio	
Bear	Collinston, Utah	6,000	.236	23.2	6.9	.300	.0708
Weber	Plain City, Utah	2,060	.081	21.8	8.5	.390	.0316
Spanish Fork	Spanish Fork, Utah	670	.026	20.8	4.5	.216	.0056
Sevier	Gunnison, Utah	3,990	.156	11.9	1.7	.143	.0223
Humboldt	Golconda, Nev.	10,800	.424	7.6	0.6	.078	.0331
Truckee	Nev.-Col. line	960	.037	39.4	19.3	.490	.0181
Carson	Empire, Nev.	990	.039	20.1	7.4	.368	.0144
Total		25,470	.999	....	....	....	.1959

Mean Run-off = 19.6%.

SOUTH PACIFIC DRAINAGE.

San Diego	Lakeside, Cal.	210	.007	14.3	3.6	.252	.0016
San Luis Rey	Pala, Cal.	320	.011	14.5	3.9	.272	.0030
Salinas	Soledad, Cal.	1,220	.043	34.4	15.7	.456	.0196
Sacramento	Red Bluff, Cal.	9,300	.329	49.9	22.6	.452	.1492
Feather	Oroville, Cal.	3,640	.129	50.8	32.5	.640	.0832
Yuba	Smartville, Cal.	1,220	.043	65.7	50.1	.763	.0328
Americus	Fairoaks, Cal.	1,910	.067	59.9	39.7	.663	.0444
San Joaquin	Rollasky, Cal.	1,640	.058	45.2	23.2	.513	.0298
Kern	Bakersfield, Cal.	2,340	.083	25.0	10.0	.400	.0332
Kaweah	Three Rivers, Cal.	520	.018	31.2	22.3	.714	.0129
Kings	Sanger, Cal.	1,740	.062	40.4	28.4	.703	.0436
Merced	Merced Falls, Cal.	1,090	.039	50.2	25.0	.499	.0195
Tuolumne	Lagrange, Cal.	1,500	.053	58.7	32.4	.552	.0293
Stanislaus	Knights Ferry, Cal.	940	.033	61.5	36.3	.590	.0194
Mokelumne	Clements, Cal.	640	.023	58.1	32.6	.561	.0129
Total		28,230	.998	....	....	....	.5344

Mean Run-off = 53.4%.

NORTH PACIFIC DRAINAGE.

River.	Above.	Area		5-Year Average			Product
		Sq. Miles	Percent.	Rainfall	Run-off	Ratio	
Klamath	Keno, Ore.	3,150	.012	29.1	13.5	.464	.0056
Rogue	Tolo, Ore.	2,020	.008	49.8	24.6	.496	.0040
Umpqua	Elkton, Ore.	3,700	.014	44.7	30.2	.676	.0095
Columbia	The Dalles, Ore.	237,000	.885	24.0	11.9	.495	.4021
John Day	M'Donald, Ore.	7,800	.029	12.0	3.5	.292	.0084
Deschutes	Biggs, Ore.	9,180	.034	22.8	10.7	.469	.0160
Willamette	Albany, Ore.	4,860	.018	52.7	38.9	.737	.0133
Total		267,710	1.000	....	....	....	.4589

Mean Run-off = 45.9%.

From a study of the above tables and a consideration of the basins of the individual rivers, some conclusions can be derived as to the various factors determining the run-off of a stream. The influences operating on the discharge of a river basin are too intimately associated and involved to allow an exact statement as to their respective importance, but certain general relations can be shown, and the relative importance of the factors judged approximately.

Run-off is, of course, primarily dependent on precipitation, but to say that the run-off varies directly as the rainfall is a broad statement which statistics fail to support. This is shown, not only for different drainage basins, but even in the same basin. Thus in the Penobscot River, above Millinocket, Me., in 1906, with a rainfall of 41.9 in., there was a run-off of 18 in., or 43 percent., while during the next year, with a rainfall of 42.1 in., the run-off was 26.9 in., or a ratio of 64 percent. Cases so extreme as this, however, are of unusual occurrence and are due to outside influences. Ordinarily it can safely be said that the percent. of run-off in any particular stream will increase with an increase in rainfall. This is well illustrated by the Columbia River, which shows the following variation:

Year.	Rainfall.	Run-off ratio.
1906	21.5	45.6%
1908	24.2	49.0
1909	24.1	50.2
1907	26.1	52.1

Even though varying with the rainfall, the run-off is not directly proportional to it, but shows much greater variation than the rainfall ever does. The maximum annual rainfall rarely exceeds four times the minimum, while the maximum run-off may exceed the minimum by several times that amount. If the rainfall and run-off should be plotted for a period of years on an equal scale, the curve of the rainfall would be found to be much the more irregular, with far sharper changes. An example of this is given by the Oconee River, above Dublin, Ga.:

Year.	Rainfall.	Run-off.	Ratio.
1906	50.1	19.6	.391
1907	45.9	14.7	.319
1908	54.3	25.2	.464
1909	49.1	18.2	.369
1910	43.3	12.4	.288

Of even greater importance than the total amount of the rainfall is its distribution throughout the year. A stream which has its precipitation concentrated in a few months will yield a higher percentage of run-off than a similar one with its precipitation distributed evenly throughout the year. The causes for this are apparent. In the former case, evaporation has a smaller opportunity to act on the water, since in a rainy season evaporation is at its poorest efficiency. Also, as the ground can hold only a certain amount of water, when it becomes saturated the remaining water can flow off as a surface discharge.

An example of this principle can be found in the Merrimac of Massachusetts and the Kaweah of California. With nearly equal annual rainfall of about 32 in., the Kaweah has 33 percent. higher run-off, the ratios being respectively 0.514 and 0.714. This is due to the concentration of 83 percent. of its total rainfall into the months from November to April, while in the Merrimac basin the precipitation is distributed very nearly equally throughout the year, with 26 percent. falling in Spring, 24 percent. in Summer, 25 percent. in Autumn, and 25 percent. in Winter. This distribution of the rainfall is of the greatest importance, and special emphasis should be placed on it in calculating water supplies.

One reason for the increase in the ratio of run-off with higher rainfall is found in the evaporation, which remains nearly constant from year to year, irrespective of the amount of precipitation. The explanation of this is that conditions favorable for high evaporation, i. e., heavy rainfall and high temperature, rarely occur together. Due to this the evaporation of a wet year is about equal in amount to that of a dry, hot year. This uniformity of evaporation, so noticeable as between years, is not found as between seasons of a single year, when, on the contrary, great differences occur. In the basin of the Sudbury River of Massachusetts, evaporation during the Summer is six times as great as during the Winter,[6] owing chiefly to the higher temperature and greater amount of sunshine during the former, and to the occurrence of ice during the latter season.

The evaporation of different streams varies widely, being dependent upon a number of separate factors. The most important of

[6] *Trans.* Am. Soc. of Civil Engineers, Vol. 27.

these is the temperature. Evaporation is directly proportional to the temperature, and will therefore be higher in warmer regions, other things being equal. It is even sufficient, in very hot regions, as some parts of the Great Basin, completely to exhaust the streams, leaving no flow in the river bed. The velocity of the wind also has an important influence on evaporation. Other factors of major importance are the roughness of the surface, the amount of sunshine, and the area forested.

Numerous attempts have been made to construct formulas by which to compute the run-off of streams from the precipitation records. Several of these are in use, but they are inaccurate and require important modifications for each stream. A formula for one stream may give fair results for a neighboring one of similar character, but to apply it to a stream in a different section of the country would be futile. The only reliable way to ascertain the run-off from rainfall data is to construct a curve for the particular stream from the records of former years, and use it as a standard.

The influence of topography on run-off is hard to gage, as it is closely associated with other factors. It is probable, though, that this is one of the less important agents in determining stream flow. Roughly, it may be stated that in a steep basin the run-off will be large but very irregular, while in a flat basin the run-off will be less, but more uniform.

Two streams which flow over the same geological formation will be found to have a close resemblance in flow. The character of the soil and underlying rock is chiefly important by its ability to hold the rain in the form of ground water. Igneous and other massive rocks, such as the pre-Cambrics of the upper Hudson valliey, give little opportunity for the rain to penetrate them, and therefore yield a relatively high run-off. At the other extreme, very porous rocks, as some sandstones and highly jointed limestones, yield little or no surface flow, but conduct the water at a deeper level, returning it to the surface at a lower point, possibly in some other drainage basin. These rocks afford a more regular flow to the streams, but the opportunities for loss are greater, and the ultimate total run-off is somewhat less than where denser rocks occur. Likewise a sandy surface soil yields a more uniform but smaller flow than where the soil is clay.

An interesting example of the influence of geological formation on the run-off is found in the basin of the Mohawk River, where those tributaries flowing from the granitic area to the north of the stream have a greater run-off than those coming from the Devonian shales to the south.[7] It must not be forgotten, however, that the area to the north is much more heavily forested, and its greater flow is undoubtedly partly due to this influence.

The proportion of a drainage basin that consists of lakes and marshes has a modifying influence on stream flow, through the ability of these to store excessive rainfall and to distribute its flow over a longer period of time. On the other hand, due to increased evaporation over a water surface, lake area decreases the total run-off of a basin to an appreciable extent. An example of high evaporation is seen in the Oswego River basin, of which 10.6 percent. consists of lakes and marshes, where the evaporation amounts to 28 in. annually. The equalizing effect of lakes on stream run-off is also well illustrated in the basin of the Androscoggin River, which has 69 square miles of lake surface.

Lakes and marshes are not the only means of storage, for over most of the country large quantities are stored in the form of ice and snow, occurring as loose drifts in the lowland, which will melt and will find their way to the streams at the first thaw, or as deep solid drifts on the mountain ranges, or more rarely in the form of permanent glaciers. Snow of the first type serves only to swell the already high streams of early Spring, without having any beneficial character. If of the latter types, the melting period is much later and more protracted, which is of great service in maintaining flow during the Summer months when all other agencies are working toward the reduction of the discharge. It is a general rule that streams which have their sources in the mountains maintain a more constant Summer flow than those rising in the lowlands. Nowhere is this better illustrated than in the streams of the Pacific Coast, where the mountains of the Coast Range are close at hand, and contain the headwaters of most of the streams.

That the vegetation of a drainage basin is of great importance in determining the amount of run-off is generally accepted, but whether the forests increase annual rainfall, as commonly believed, has not

[7] Rafter, in *Water Supply Paper*, No. 80, p. 47.

been proved. Indeed, it is now considered very doubtful whether any difference in rainfall can be traced to the influence of vegetation. The real value of vegetation, and particularly of forest growth, is in restricting the evaporation of the rain that does fall. Plants somewhat counterbalance their effectiveness in this direction by the water which they consume themselves, but the balance is well in their favor; and if, of two similar watersheds, one is heavily forested and the other is not, the run-off from the forested basin will exceed that from the other.

The effectiveness of the vegetation depends largely upon its character. The best type is old coniferous forests which allow little wind and less sunshine to penetrate their depths. Where extensive areas of such forests occur the run-off is sure to be high. Deciduous growth is not so influential, yet is still of value, and even cultivated fields are of some, though limited importance. The means by which the increased run-off is produced are several. First is the restriction of evaporation, due to the inability of the wind to circulate freely among the trees, to the maintenance of lower temperature and higher humidity during the Summer months, and to the protection which the foliage gives from the sunshine. Aside from the lessening of evaporation, forests provide conditions favorable for the accumulation of snow drifts and their preservation until after the time of the Spring floods. The ground-water circulation is also increased by forests. Examples of high run-off from heavily forested regions are common, but the Machias, Mohawk and Umpqua Rivers are excellent illustrations.

In spite of the prominence of forests in governing the run-off from an area, other factors may combine to overcome its influence; as a result, some basins show low or irregular run-off notwithstanding their being heavily forested. This is well shown by the streams of western Oregon and Washington, which, although well protected by forests, are subject to floods, due to heavy and concentrated rainfall.

The recent disasters in Ohio and Indiana have brought the general subject of floods prominently before the public mind, and the study of their causes and occurrence is of special interest. It has been noticed of late years that floods have been increasing in frequency and a study of the records of almost any stream subject to

floods will prove this. On the Allegheny River, during the period from 1874 to 1890, floods occurred in only three years, while during an equal period, from 1891 to 1907, there were ten years when floods occurred. Likewise, on the Savannah River, from 1876 to 1890, there were three years with floods; while during the years 1892 to 1906, there were five years with floods. These rivers indicate fairly well the change in conditions throughout the eastern states.

The explanation of this increase must lie in a change of one of the influences governing run-off. Records show that rainfall and temperature have not changed; the topography and geology of a river basin are permanent, for this discussion; artificial agencies tend to check rather than encourage floods; hence the prime cause must be a change in vegetation, chiefly deforestation. The records sustain this supposition by proving that it is those very basins that have been most denuded of their forests which record the greatest increase in the number of floods. Thus, on both the Allegheny and the Savannah river basins large lumbering industries have been at work during recent years, and the increase in the number of floods can be traced directly to this cause.

In conclusion it should be emphasized that the solution of the problems herein discussed is not final, because reliable records over long periods of time are not available, and little attention has yet been paid to this important subject.

GRAB SAMPLING.

BY E. H. DICKENSON.*

In view of the frequent use made of grab sampling, the following figures may be of interest. A small copper mine on the Alaskan coast ships its ore to the smelter by steamer. This ore is loaded into the freight boats by hand tramming, the cars holding about one ton each. The ore is of medium grade and consists of chalcopyrite and pyrite in greywacke and slate. During loading, a grab sample is taken from each car by a man stationed on the loading dock for this purpose. This sampling is entrusted only to experienced and careful men who endeavor to take the same weight from each car and to make the sample as representative as possible. The weight of sample taken averages about 2 lb. per car. As the following screen analysis will show, the values do not tend to segregate in the fines to any marked extent:

Through.	On.	% of Total Weight.	% of Total Cu. in Product.
40 mesh	60 mesh	30.6	24.8
60 "	80 "	9.5	8.7
80 "	100 "	6.6	7.0
100 "	..	53.3	59.5
		100.0	100.0

This ore is again sampled in the regular sampling mill at the smelter. The following figures compare the results of grab sampling with those obtained by mechanical sampling at the smelter. The figures are based on two years' work, on shipments varying from 200 to 2000 tons each. The differences are expressed as a percentage of the true copper content of the ore:

Average difference between grab and mechanical sample	7.1
Maximum difference between results	28.6
Percentage of cases in which the grab sample was high	55.0
Percentage of results over 10 percent. wrong	30.0

Applying these figures to three ores running, say, 2 percent., 10 percent., and 20 percent., copper, we would get the following results:

	2% Ore	10% Ore	20% Ore
Average error of grab sample	0.14%	0.71%	1.42%
Maximum " " " "	0.57	2.86	5.72
Error to be expected in 30% of the results	0.20	1.00	2.00

*E. M., Columbia, 1911. With the Beatson Copper Co., Latouche Island, Alaska.

The conditions at this mine are very favorable for grab sampling. The men doing the work are all interested in the results, and the samples are cut down and assayed with the greatest care. The fact that 45 percent. of the results of grab sampling are low is, I believe, not what would generally be expected.

In many mines samples are taken by grabbing a few pieces from the face or from the ore broken by each round. The error in samples of this kind would probably be several times greater than that shown above; results obtained in that manner are not only useless but dangerously misleading.

ABSTRACTS—ANALYTICAL CHEMISTRY

BY ELWYN WALLER.

APPARATUS — REAGENTS — MANIPULATION.

Tantalum Electrodes.— Wegelin. (*Chem. Ztg.*, XXXVII, 989.) The use of Ta electrodes has been recommended because the metal is cheaper than Pt, and is very resistent to conc. HNO_3, $K_2Cr_2O_7$ + conc. H_2SO_4, etc. As a cathode for Zn determinations in alkaline solutions it was found to be unusable; results even approximately correct could not be obtained. With Cu the deposition was very slow, though eventually complete.

Brunck (*ib.* XXXVI, 1233) recommends the use of Ta as cathode; as anode it soon becomes covered with a badly conducting film of oxide, a condition which can be prevented by plating with a film of Pt.

Inorganic indicator in alkalimetry.— Reichard. (*Pharm. Zentrhalle*, LIII, 1033) Freshly made BiOOH, suspended in H_2O containing KI, gives no coloration unless heated or when free acid is present (except CO_2). The yellow color is discharged by alkali. To make the indicator, dissolve 0.1 gm. $BiONO_3$ in 1 c.c. of 25 percent. HCl, and 5 c.c. H_2O. Add 0.5 gm. KI and dilute slowly to 400 c.c.; let stand a few days, and then decant the clear yellow green solution for use. The solutions titrated should be not less than N/4 in strength, and the acid must be the titrating liquid.

Fluorine in reagents.— Carles. (*Bull. Soc. Chim.*, XIII, 553). In conducting researches on the presence of F in sea water, plants, etc., it became necessary to test the reagents used. The conclusions are: H_2SO_4 and HCl are usually, though not always, free from F. HNO_3 free from F does not exist; the same may be said of KNO_3 and $NaNO_3$. Commercial $Ba(OH)_2$ is surcharged with F, but as that remains insoluble, its solutions are free from F. $BaCl_2$ is usually free; the acetate is not always so. $NaHCO_3$ or $KHCO_3$ are rarely free from F. $(NH_4)_2CO_3$ always contains it. Glacial acetic is free.

New Reagent for Nickel.—Atack. (*Analyst*, XXXVIII, 316). The reagent is alpha-benzil dioxime. With Ni it gives $C_{28}H_{22}N_2O_4Ni$, an intensely red precipitate. The mode of application (NH_4OH solution, etc.) is similar to that with dimethyl glyoxime, but it is much more sensitive. The precipitate is more voluminous, and contains but 10.93 percent. Ni. It is not advisable to use it with amounts of Ni greater than 0.025 gm. Nitrates must be excluded when using it. Large amounts of Cu interfere. Weighing must be done with counterpoised filter papers; ignition methods appear to be inapplicable.

Amalgamated Aluminum for Marsh Apparatus.— Kohn-Abrest. (*Ann. Falsif.*, V, 584.) Wash about 4 gm. Al (in foil or small pieces) with HNO_3; then immerse 4 min. in 25 c.c. of a 1 percent. $HgCl_2$ solution. Rinse off and use in Marsh app. with 220 c.c. H_2O. Acid is not necessary. Let run for 2 hours, and then introduce the solution to be tested.

The method is not especially sensitive, but makes it easy to obtain reagents free from As.

Neutrality of salts on boiling.— Fort. (*J. Soc. Dyers and Col.*, XXVIII, 314) Using alizarin, it was found that Na_2SO_4, K_2SO_4, and $NaNO_3$ gave an alkaline reaction; NaCl, KCl and KNO_3 did not. Also weak bases, such as aniline, liberate a little of the base from Na_2SO_4, NaCl, etc.

Nitric acid in Sulfur trioxide.— Ivanhoff. (*Chem. Ztg.*, XXXVI, 1170) If more than 20 percent. SO_3 is present, diphenylamine gives a coloration, due to the oxidizing action of the SO_3. In making the test, therefore, enough H_2O must be added to bring the oxide to the condition of H_2SO_4.

Separation of nitrous and nitric acids.— Fischer and Steinbach. (*Zts. anorg. Chem.*, LXXVIII, 134) Esterification of the HNO_2 is the method applied. Place the mixture in a 300-c.c. flask, add 5 c.c. methyl alcohol, and allow N/10 HCl containing a little methyl alcohol to drip into it, while passing a current of air. After 20 c.c. of the acid has been added, stop further addition, and continue passing air for 5 min. Then titrate with standard NaOH free from carbonate, using phenolphthalein indicator. Reaction is $NaNO_2 + HCl + CH_3OH = NaCl + CH_3.O.NO + H_2O$.

Or, mix the solution with methyl alcohol, and run it drop by drop into a flask containing H_2SO_4 and methyl alcohol, passing air through the mixture at the same time. In the liquid remaining, HNO_3 can be determined by distilling with KOH and the Devarda alloy, and estimating NH_3.

Ammonia Distillations.— Winkler. (*Zts. angew. chem.*, XXVI, Aufsatzth. 231.) Instead of distilling into standard H_2SO_4 or other acid, and then titrating back, the NH_3 may be absorbed by H_3BO_3 solution, and then titrated directly with standard acid using methyl orange or congo red indicator.

Carbon determinations.— Hart and Woo. (*J. Am. Chem. Soc.*, XXXV, 1056) The method consists in fusing a weighed amount of the substance with Na_2O_2, dissolving, acidifying, and distilling over the CO_2, which is eventually titrated with phenolphthalein. Take 0.1 to 2 gm. of the material, according to its probable content in C; mix with 6 gm. Na_2O_2 in a crucible, which may be of Fe or Ni (or even porcelain if the latter is smooth). The covered crucible is placed inside of another, which is also covered, and that is set in a hole in an asbestos board for heating. Heat 3 to 5 minutes after the first reaction occurs. For distilling, a modified Bowser apparatus is recommended.

Calcium as tungstate.— St. Germin. (*C. Rend.*, CLVI, 1019) Bring the solution to boiling, and add a 20 percent. solution of Na_2WO_4. Octahedral crystals of $CaWO_4$ separate (Sp. Gr. 6 and over). Filter on tared filter and dry at 100°. Ignition gives low results. CaO factor, 0.1944. Ca factor, 0.1307. Filtrate can be used for Mg determination.

Removing Phosphoric acid from solutions.— Mecklenburg. (*Zts. anal. Chem.*, LVIII, 293) The solution should contain no Cl, but should have 15 percent. (vol.) HNO_3. Then addition of sufficient metastannic acid, and boiling for 15 min. will remove all P_2O_5. The metastannic acid for the purpose is made by treating 150 gm. granulated Sn with 1500 c.c. HNO_3 (Gr. 1.2) in a flask cooled to 0°. When all is dissolved, the liquid is poured into 10 litres of H_2O. The precipitate is washed by decantation and filtration, and bottled moist. Small amounts of Fe_2O_3 and TiO_2 are also taken up by the reagent.

Nitrates; Phenol-sulfonic method.— Kelley. (*J. Am. Chem. Soc.*, XXXV, 775) Lipman and Sharp have noted that in presence of Na_2SO_4 some loss of nitrate occurs on evaporating. As investigation by the author has shown that K_2SO_4 or $(NH_4)_2SO_4$ has the same effect, but $CaSO_4$ or $MgSO_4$ do not interfere. If Na_2CO_3 is added before evaporation, the loss does not occur. It is attributed to a slight hydrolysis of the alkaline sulfates on evaporating a neutral solution.

Nitrous acid in presence of ferric salts.— Artmann. (*Chem. Ztg.*, XXXVII, 501.) Addition of sufficient pure Na_2HPO_4 to convert all the Fe_2O_3 to phosphate prevents reaction of Fe_2O_3 salts with KI, but has no effect on the reaction between HNO_2 and KI. Add a little H_2SO_4 and titrate with standard $Na_2S_2O_3$.

Lead in chemicals.— Elsdon. (*Pharm. J.*, LXXXIX, 143) In filtering weak solutions containing Pb salts, much Pb is absorbed by the paper unless at least 0.6 percent. acetic is present.

Hydrazine and Ferricyanide.— Ray and Sen. (*Zts. anorg. Chem.*, LXXVI, 380) With alkaline solution of $K_3Fe(CN)_6$ hydrazine salts react vigorously, affording $K_4Fe(CN)_6$ and N_2 gas, which can be measured in an eudiometer. The reaction can be utilized either to determine hydrazine or to determine ferricyanide.

Barium Sulfate — Filtration.— Krak. (*Chemist Analyst*, No. 5, 26.) After decanting the supernatant solution, stir with 10 c.c. sat'd, slightly acid solution of $NH_4C_2H_3O_2$. The precipitate becomes coarsely granular and filters more readily.

Reduction of Ferric Salts for Permanganate Titration.— Le Clerc. (*J. Pharm. Chim.*, VII, 587.) To the solution in a flask add a little granulated Zn, a strip of Pt, excess of H_2SO_4, and 2 to 3 gm. $(NH_4)_2SO_4$. The latter is in order to form the stable $Fe(NH_4)_2(SO_4)_2$. Effect the reduction by heat, filter through glass wool, and titrate as usual.

Acidimetric Titration of Arsenic Acid.— Menzies and Potter. (8th Int. Cong. App. Chem., I, 367) Adding solution of $BaCl_2$, and boiling, causes the substitution of HCl for H_3AsO_4, and the titration is more readily performed after cooling the solution.

Soluble Silica in Trass.— Hambloch. (*Chem. Ztg.*, XXXVI, 1058) Use of KOH is best avoided. Preferably, use a freshly prepared 5 percent. NaOH, the mineral being "not too finely powdered." It is noted that other substances besides SiO_2 may be dissolved by the alkali.

Tungstic and Silicic acid.— Hermann. (*Zts. Anal Chem.*, LI, 736) With excess of WO_3 and a suitable degree of acidity, the complex SiO_2. 12 WO_3 will form. Free mineral acids prevent its formation, but once formed it is almost impossible to break it up. Digesting a solution of Na_2WO_4 with SiO_2 in a solution acidified with acetic will cause its formation, so that the SiO_2 present may be determined by estimating the WO_3 remaining.

Arsenic from Tungsten.— Hilpert and Dieckmann. (*Ber.*, XLVI, 152) These elements when together in the same solution form complex compounds, which are so stable that a separation is exceedingly difficult. H_2S precipitates a little of the W but no As. By distilling a mixture of the two acids with 15 gm. CuCl and 150 c.c. HCl (1.16) carrying the distillation very low, the As was forced into the distillate. The experiments were made with solutions containing up to 0.2626 gm. WO_3, a proportion that it seemed best not to exceed. Repetition of the distillation may be necessary. Retention of As on the surface of precipitated WO_3 by adsorption seemed to occur. After a second distillation, heating with strong KOH, and then re-acidifying and distilling were effective.

Prussian-blue Test.—Vorländer. (*Ber.*, XLVI, 181) An investigation made with dilute solutions shows that ferrocyanide reacts readily with ferrous salts, the reaction being but little influenced by the presence of salts or of free acid, whereas with ferric salts, free acid or salts delay, and may entirely prevent a reaction, so that oxidation to ferric as a preliminary is unnecessary. Also in the test for cyanide the use of ferric salt had best be omitted.

Detection of Hyposulfite.—Pozzi-Escot. (*Bull. Soc. Chim.*, XIII, 401)· To 1 or 2 c.c. of the test solution add an equal volume of 10 percent. solution of $(NH_4)_2MoO_4$, then run in gently some conc. H_2SO_4 so that it forms a layer at the bottom. If hyposulfite is present a blue layer forms at the junction of the two solutions. 0.00005 gm. $Na_2S_2O_3$ can be readily detected. The reaction is due to reducing action of $H_2S_2O_3$ which is set free in dilute solutions but in more concentrated solutions is split up into H_2SO_3 and H_2S.

Ores and Metallurgical (Non-ferrous) Products.

Volumetric for Gold.—Lenher. (*J. Am. Chem. Soc.*, XXXV, 733) To obtain an $AuCl_3$ solution free from Cl on the one hand, and from AuCl on the other, dissolve the metal in HCl and $KClO_3$, neutralize the free Cl by slight excess of NH_4OH, and then acidify with HCl. In such a solution KI gives AuCl and I_2, which may be titrated with $Na_2S_2O_3$. KBr reacts similarly, the Br set free is titrable with standard SO_2 solution. NaCl with KI gives a yellow color titrable to colorless by standard SO_2. $MgCl_2$ gives a more pronounced yellow color, titrable in the same way. The SO_2 solution is standardized by $KMnO_4$. Frequent restandardizing is necessary.

Methods in Mints.— French. (*Min. and Eng. World*, XXXVII, 853) For Au a solution as $AuCl_3$ absolutely free from free Cl is precipitated

by a standard solution of Mohr's salt (153.5 gm. per litre + 1 c.c. H_2SO_4; 1 c.c. = 0.025 gm. Au) and the excess titrated back with standard $KMnO_4$. For small amounts of Au, excess of KI is added, affording AuI dissolving in excess of KI and free I which is titrated with standard $Na_2S_2O_3$. With Ag bullion, in many cases the Volhard KCNS method is used.

Separating Silver and Mercurous Hg.— Von Tweigbergh. (*Svensk. Kem. Tidskrift,* XXV, 92) Treating the HCl precipitate with NH_4OH leaves behind some Ag in the form of an amalgam. By boiling with dilute HNO_3, and adding NaClO in small portions at a time until NH_4OH gives no blackening, the Hg is oxidized higher, and the Ag can be detected, at least when in proportion of 1:300 Hg.

Platinum — Precipitation as sulfide.— Gaz. (*Apoth. Ztg.,* XXVII, 959) The device used in other relations is recommended — adding not less than 0.5 percent. nor more than 10 percent. of $HgCl_2$ solution and warming to 80° or 90° both before and after passing H_2S. After filtering and washing, ignition affords metallic Pt.

Zinc and Nickel Separation.— Cockburn and Gardiner. (*Analyst,* XXXVIII, 443) Neutralize the solution with Na_2CO_3, add 100 c.c. glacial acetic, dilute to 200–260 c.c. and pass H_2S cold for 1 hour. Test analyses have shown the separation to be practically complete. Preference is however expressed for Waring's method — precipitation from solution just acid with formic, which is not quite so complete. The dimethyl glyoxime method appears to be the most convenient and accurate.

Zinc Silicates, etc.— Voight (*Zts. angew. Chem.,* XXVI, 47) In slags or ores when the Zn is present principally as silicate, decomposing with HCl and precipitation with NH_4OH leaves all the Zn in solution, provided a considerable excess of NH_4Cl is present; either that salt must be added, or a considerable excess of HCl used in dissolving.

Spelter Analysis.— Ericson. (*J. Ind. Eng. Chem.,* V, 401) Treat 19.2 gm. with either 200 c.c. H_2O and 43 c.c. conc. HCl, or with 100 c.c. H_2O and 50 c.c. dil. H_2SO_4 (1:3). If Cd is to be determined let stand over night; if not, a few hours' standing will suffice. The metallics should still contain Zn. Filter and wash by decantation. Rinse the metallic back into the beaker; add 10 c.c. conc. HNO_3 and boil off the fumes. Any cloud of SnO_2 or SbO_2 should be filtered off. Dilute, add 30 c.c. strong NH_4OH, and 5 to 10 gm. ammonium persulfate, the amount depending upon the amount of the metallics. Boil 5 min. and then allow to settle 10 min. Filter off the PbO_2 while the solution is still warm, wash 4 times with hot 10 percent. NH_4OH, then 5 times with hot H_2O. Rinse back into the original beaker. Add 25 c.c. H_2O_2 solution (prepared by diluting 10 to 50 c.c. U.S.P. H_2O_2 sol. to 1 liter and adding 50 c.c. HNO_3). Stir until PbO_2 disappears. If it does not, use 25 c.c. more of H_2O_2 solution and stir as before. Then add 15 c.c. HNO_3 (Gr. 1.2) and 75 c.c. H_2O, and titrate excess of H_2O_2 with standard $KMnO_4$ (0.568 gm. liter). Titrate a blank of 25 c.c. of the

H_2O_2 solution with the $KMnO_4$. Theoretically, Fe standard $\times$ 1.851 = Pb standard. In practise, the correct factor has been found to be 1.92.

The ammoniacal filtrate contains Cd and Cu as well as some Zn. Boil to neutrality, add 40 c.c. dil. H_2SO_4, and precipitate by H_2S. Filter and wash; pour warm dil. HCl through the filter, which leaves CuS. Neutralize the filtrate with NH_4OH, add 8 gm. trichloracetic, and precipitate Cd by H_2S. Fe is determined on a separate portion of 10 gm. treated with 75 c.c. dil. H_2SO_4, adding a few drops of $PtCl_4$ at the end; titrate with standard $KMnO_4$.

Separating Cadmium from Zinc.— Treadwell and Guiterman. (*Zts. anal. Chem.*, LII, 459) The solution (of sulfates) should contain H_2SO_4 in amount sufficient to make it 4 to 5/N. Heat, and pass H_2S until cold. If the Zn is equal or greater in amount than the Cd, redissolve precipitate in HCl, evaporate to fumes with H_2SO_4, dilute, and repeat H_2S treatment.

Alumina from Chromium.— Jakob. (*Bull. intern. acad. Sci. Cracovie,* 1913 [*A*] 56.) The solution should be about 100 c.c. without large excess of free acid. Put into a flask, and add 20 percent. NaOH solution gradually until the precipitate which first forms redissolves. Then add saturated Br water in small lots, at intervals of a half minute, until the solution loses the green of Cr_2O_3 and shows yellow (Na_2CrO_4). Heat to boiling, and add Br water slowly enough as not materially to stop the boiling, until the Br color shows that excess is present. Boil out the excess, which precipitates $Al_2(OH)_6$. Filter and wash. Some precipitate will adhere to the flask; rinse out with dil. HNO_3, precipitate that with NH_4OH, and add to the main precipitate.

Bauxite.— Martin. (*Monit. Sci.*, [5], III, 232) To avoid working with solutions containing so much alkali salts as result from direct fusion, 1 gm. of the sample, ground to 80 mesh, is digested with 15 c.c. aqua regia and 30 c.c. of 50 percent. H_2SO_4. The portion insoluble from this treatment is fused with $NaHSO_4$. Filter off SiO_2, and bring the combined solutions up to 500 c.c. In 200 c.c. of this, by NH_2OH precipitate mixed Al_2O_3, Fe_2O_3, and TiO_2; filtrate for CaO. In 250 c.c., TiO_2 can be separated by $NaHSO_3$, etc., and boiling, Fe being determined in the filtrate; Al_2O_3 is estimated by difference.

Detecting Nickel in Plated Ware, etc.— Fortini. (*Chem. Ztg.*, XXXVI, 1461) The reagent consists of 0.5 gm. dimethyl glyoxime dissolved in 5 c.c. strong alcohol, to which is added 5 c.c. NH_4OH. Clean the surface to be tested with a little ether, and then apply a drop of the reagent. If Ni is present a rose colored spot appears.

Assay of Tin Ore.— Caspell and Beniger. (*Lond. Min. J.*, 1913, 149) Roast the pulverized ore. If it contains Cu pyrites, treat with acid to remove Cu. An amount equivalent to 2 gm. of the original sample is mixed with ZnO, and put on top of a small piece of Zn in a crucible. Cover and heat to 1000° C. for 10 min., cool, transfer the mass to a flask, add 50 c.c. HCl, and boil gently 5 min. Stir gently with a coil of Ni wire to reduce any $SnCl_4$ that may have formed. Cool in an atmosphere of CO_2, and titrate with standard I.

Qualitative for Tin.— de Guzman. (*Chem. Ztg.*, XXXV, 797) The reagent consists of 15 gm. NH_4CNS in 250 c.c. H_2O, to which is added 1 c.c. HCl solution of $(NH_4)_2MoO_4$. Stannous salts give a carmine red color. Sensitiveness is greater than with $HgCl_2$. Sb salts give the reaction, but so slowly that the metals are readily distinguished. Avoid excess of HCl or of Mo salt.

Separating Antimony and Tin.— Huybrechts. (*Bull. soc. chim. Belge*, XXVII, 66) Instead of oxalic acid, addition of $Na_4P_2O_7$ to an acid solution will prevent precipitation of SnS_2 while allowing Sb sulfides to separate. Metz (*Zts. anal. Chem.*, XLIV, 532) has proposed the use of H_3PO_4 in the same way for this purpose.

Volumetric for Tin.— Zschokke method.— Fichter and Müller. (*Chem. Ztg.*, XXXVII, 309) Solution of $KBrO_3$, standardized by means of KI and $Na_2S_2O_3$, is used. The Sn is reduced in HCl solution to $SnCl_2$. The reaction is $3SnCl_2 + 6HCl + HBrO_3 = 3SnCl_4 + HBr + 3H_2O$. When all Sn is oxidized the end reaction is appearance of the yellow of free Br in the solution.

Lead in Tin.— Vannier. For plating, or solder, not over 0.5 percent. Pb should exist in the Sn. Dissolve 0.1 gm. in 1 c.c. HNO_3, and separate the SnO_2 by evaporation, etc. In the filtrate determine Pb colorimetrically by adding 1 c.c. 40 percent. KI solution, comparing with standard solutions containing known amounts of Pb. Allow to stand 5 min. before comparing.

Antimony and Tin in Alloys — Qualitative.— Belasio. (*Giorn. farm. chim.*, LXI, 499) Behren's reaction is used. Reagent is 1 gm. each of KI and CsCl in 5 c.c. H_2O. With Sb, this gives a CsSb iodide, crystallizing out in orange red hexagons. With Sn, a CsSn iodide — white crystals — forms. Both are but slightly soluble in dilute acids. When both are present, the Sb compound appears to form more readily.

Antimony-Tin Alloys. Ponto. (*Ann. chim. anal.*, XVIII, 47) If Cu is low, dissolve 0.5 gm. in HNO_3 (Gr. 1.3) evaporate to a syrup, dilute and filter, eventually weighing SnO_2 with Sb_2O_4. Another 0.5 gm. is dissolved in HNO_3 and evaporated to dryness, then digested with 1 c.c. sat. sol. Na_2CO_3 and 60 to 75 c.c. Na_2S (Gr. about 1.15). Filter cold, washing with Na_2S solution. Add 20 c.c. of 20 percent. KCN and electrolyze (current 0.3 amp.). Treat the deposited Sb with HNO_3, and weigh up Sb_2O_4. Calculate Sn by difference from weight of mixed oxides. If Cu is high, dissolve 0.5 gm. in HCl with a little HNO_3, evaporate to 5 c.c., add 50 c.c. HNO_3, boil out N oxides, add a pinch of $KClO_3$, and boil 25 min. Dilute the solution with equal volume of H_2O, and let settle for 12 hr. The mixed oxides will then be free from Cu.

Copper Alloys.— Fairchild (*Met. Chem. Eng.*, XI, 380) For bronzes, dissolve in 15 c.c. HNO_3 (1:1) and evaporate to a syrup. Add 5 c.c. more acid with 50 c.c. H_2O, boil and filter, washing with solution containing 2 percent. each of HNO_3 and NH_4NO_3. Solution is for Cu, Zn, etc. Rinse precipitate back into the beaker and dissolve in 5 gm. $(NH_4)_2C_2O_4$, with 5 gm. $H_2C_2O_4$ and 1 gm. NH_4Cl. Boil till clear, then

add the filter paper and disintegrate by boiling, then filter again. Heat to about 95° C. and treat with H_2S for 45 min. The adhering Cu, which amounts to 0.1 percent. or less, is thus recovered, along with Sb. The latter can be dissolved out by use of KOH. The oxalate solution containing Sn is boiled to expel H_2S, and electrolyzed with a current of 0.8 amp. per dec.^{2} passing a slow stream of air through the solution. The anode wire is passed through the stem of an inverted funnel to prevent loss by the bursting of the bubbles. A rate of 2 bubbles per sec. suffices. Deposition is complete in 2½ hr. Provision should be made that not over 0.2 gm. Sn is present. The united Cu and Pb solutions can be deposited from HNO_3 solution by a current of the same strength. P, if present, can be determined in the solution from the Sn. Solution from Cu and Pb contains Zn, Fe, etc. Evaporate in a casserole, and bake until NH_4NO_3 is volatilized; cool, add 1 c.c. conc. H_2SO_4, and heat to bring Fe, etc., into solution. Dilute, add 5 gm. NaOH and a little Na_2O_2, with 50 c.c. H_2O. Heat for a few minutes, and filter through asbestos. If over 20 percent. Zn is present, electrolyze only half of the solution. Add NaOH to bring the strength up to 10 percent., and electrolyze at 60° C. Deposition is complete in 2 to 2½ hr. Mn, if present, is with the Fe on the asbestos filter. The bismuthate method can be used. Otherwise Fe can be dissolved from the filter with HCl and estimated with KI and $Na_2S_2O_3$.

For white metals, method of G. W. Thompson with modifications is advised.

Copper — Volumetric.— Demorest. (*J. Ind. Eng. Chem.*, V. 215) The method of Guess consists in precipitating as $Cu_2(CNS)_2$, treating with NaOH, then acidifying and titrating the CNS with $KMnO_4$. Theoretically, all the S is oxidized to SO_3. In practise, about 5 percent. shortage is noted. If the $KMnO_4$ is added to the alkaline solution, until nearly enough has been used, acidifying and finishing in the acid solution gives correct results. To H_2SO_4 solution of the sample add 3 gm. tartaric, add NH_4OH in excess, acidify with H_2SO_4, add 1 gm. Na_2SO_3, heat nearly to boiling, add 1 gm. KCNS in solution slowly. Continue the heat for some minutes, filter and wash thoroughly, then pour through the filter 20 c.c. of 10 percent. NaOH. Wash. Warm the solution to 50° and then run in standard $KMnO_4$ with agitation until a drop acidified with HCl gives a faint red with $FeCl_3$ solution. Then add 30 c.c. of (1:1) H_2SO_4 and finish the titration. Fe standard $\times$ 0.1897 = Cu standard.

Copper.— Re-solution in Electrolysis.— Gilchrist and Cumming. (*Chem. News*, CVII, 217.) When deposited from HNO_3 solution, there is often a slight re-solution of Cu, when removing the electrode and breaking the circuit. Addition of 5 gm. urea will prevent this by destroying HNO_2.

Traces of Arsenic or Antimony.— Staddon. (*Chem. News*, CVI, 199) Obtain a *neutral* solution of 0.5 to 2 gm. in 5 c.c. H_2O. Add 0.5 to 2 gm. of "blankit" (commercial name for Na_2SO_2) and warm. Brisk reaction occurs, and after a few seconds, a brownish precipitate

of elemental As or Sb separates, if either is present. Addition of NaClO will dissolve As, but leave Sb (black) undissolved.

Phosphoric acid in Apatite, etc.— Moeser and Frank. (*Zts. anal. Chem.*, LII, 346) Add 4 to 6 c.c. conc. H_2SO_4 to 0.3 to 0.5 gm. of sample, and boil 10 or 15 min.; cool, add 30 or 40 c.c. of 95 percent. alcohol, and (to facilitate filtration) 2 c.c. of 10 percent. alcoholic solution of KOH. Settle, filter, and wash with alcohol. P_2O_5 is held in the solution. Dilute with H_2O and precipitate with Mg mixture.

Red lead.— Determining PbO_2.— Finzi and Rapuzzi. (*Zts. anal. Chem.*, LII, 358) Acidified solution of hydrazine acetate reduces PbO_2, evolving a proportionate amount of N_2. Fit a flask with a cork carrying a stop-cock funnel, and delivery tube which is connected with a eudiometer. Weigh out about 1 gm. of the sample in the unstoppered flask, add 30 or 40 c.c. H_2O, boil out the air and cool to room temperature. Then adjust the cork, and from the stop-cock funnel run in 20 c.c. of a solution containing 12 percent. hydrazine acetate and 10 percent. acetic. Make the reaction complete by warming the flask; then measure the N evolved. Experiment showed that the results are invariably 1.07 percent. too high, so that the empirical factor 0.01981 gm. PbO_2 for 1 c.c. N at 0° and 760 mm. must be used.

Lead in small amounts.—Elsden and Stanfield. (*J. Lond. Chem. Soc.*, CIII, 1039) Add $FeCl_3$ in amount sufficient to give 10 times as much Fe as Pb presumably present. Precipitate by NH_4OH; boil, and filter. Dissolve through the filter with 10 to 20 c.c. hot HCl, and wash the paper with hot H_2O until the bulk is about 75 c.c. Neutralize with NH_4OH until a slight permanent precipitate forms; then add N/2 HCl — at least 10 c.c.— more if necessary to make it 2 c.c. per 0.1 gm. Fe. Then add at least 1 gm. Na_2SO_3 or enough to make it 0.2 gm. per 0.1 gm. Fe. Warm until complete reduction supervenes. Add 10 to 20 c.c. of 10 percent. NH_4Ac and then slowly run in 5 percent. $(NH_4)_2MoO_4$ solution (10 to 20 c.c.). Boil a few minutes, and filter. Wash with hot H_2O. As the precipitate contains a little Fe, dissolve through the filter with 10 c.c. dil. HCl, wash to bring the bulk to 50 c.c., add a little tartaric, neutralize with NH_4OH, using an indicator; then acidify with a few drops of N/2 HCl, add a little NH_4Ac, and boil to bring down $PbMoO_4$ again. Wash, ignite, and weigh.

Coke.— Report of Committee on Standard Methods. (*Trans, Am. Foundrymen's Assoc.*, 1912, 143) Detailed description of methods for sampling are given. *Moisture.*— Dry 1 hr. at 104 to 107° C. *Volatile.*— The crucible containing the dried sample is supported inside of another, leaving about ½ in. space. Ignite 3½ min. over a burner and 3½ min. over a blast. *Fixed C and ash.*— Burn off in the ordinary manner. *Sulphur.*— Mix 0.7 gm. of sample (80 mesh) with 12 gm. Na_2O_2 and 0.5 gm. powdered $KClO_3$ in Ni crucible of 40 c.c. capacity. Support the crucible in a 600-c.c. beaker containing H_2O enough to immerse the lower half. Put on the cover, which has a hole in the centre, through which is introduced a red-hot wire to fire the charge. After firing, dissolve in the H_2O, remove support and crucible. Add HCl to dissolve,

then slight excess NH_4OH, and filter. Using methyl orange, neutralize with HCl, and then add 0.5 HCl in excess. Precipitate with 10 c.c. $BaCl_2$ solution added slowly to the boiling solution. Boil 15 min., stand 2 hr., and filter. *Phosphorus.*— Burn 5 gm. to ash. Treat with 10 c.c. HCl and 20 c.c. HF. Evaporate to dryness, and fuse with 1.5 gm. Na_2CO_3 and 2 gm. KNO_3. Dissolve, etc., precipitate with NH_4OH, dissolve in HNO_3 and precipitate with MoO_3 mixture. The acidimetric method is applied.

Calorimetric Estimation of Alkaline Earths, etc.— Fortini. (*Ann. Lab. Chim. Centr. de la Gabelle,* VI, 509) Place 25 c.c. of HCl (1:1) in a Dewar vacuum tube. Note the temperature and then add 0.5 or 1 gm. of the material. (Partly calcined $MgCO_3$, asbestos mixtures, etc.) and note the rise in temperature. It will be proportionate to the amount of base (CaO, MgO, etc.) present. The particular tube used, strength of acid, etc., must be standardized with known amounts of pure CaO, MgO, etc. Under the conditions used by the author, 1 gm. CaO or of MgO gave a rise respectively of 38° and 37°. With 0.1 gm. of either the rise was $\frac{1}{10}$ that amount, and so on. Admixture with carbonates, asbestos, glass wool, etc., did not influence the indications.

Neutral Ammonium Citrate.— Bell and Cowell. (*J. Am. Chem. Soc.,* XXXV, 49) The method proposed depends on these facts. NH_3 is slightly soluble in chloroform; Citric and $NH_4Cit.$ are insoluble. At ordinary temperatures, between equal volumes of $CHCl_3$ and H_2O, $\frac{1}{26}$ of the NH_3 will be in the $CHCl_3$ and $\frac{25}{26}$ of the NH_3 in the H_2O layer. By shaking up a measured amount of the solution with $CHCl_3$, and titrating for NH_3, the amount of acid necessary to give a neutral solution can be found. Also by careful determination of the point at which the temperature ceases to rise (test made in a Dewar flask) on adding NH_4OH to the acid the exact point of neutrality can be obtained.

Volumetric for Hydrofluoric Acid.—Greef. (*Ber.,* XLVI, 2511) Adding $FeCl_3$ solution to neutral solution of NaF precipitates what the author terms Iron-Kryolite: $6\ NaF + FeCl_3 = Na_3FeF_6 + 3\ NaCl$. The precipitate is insoluble in H_2O and does not react with thiocyanate. A volumetric method using standardized $FeCl_3$, with KCNS as indicator, is proposed. The end reaction in H_2O solution is not very sharp, but can be made more so by adding a mixture of alcohol and ether, when the coloration appears in the ether layer. Presence of much NaCl in the solution increases the sharpness. Dissolve 0.5 gm. of the material in 25 c.c. hot H_2O in an Erlenmeyer; cool, add about 20 gm. NaCl, and 5 c.c. KCNS solution (200 gm. per litre). Titrate with the $FeCl_3$ solution until the solution is pale yellow. Add 10 c.c. alcohol and 10 c.c. ether, shake well together, and continue adding $FeCl_3$ until the ether layer cannot be made to lose the red tint by shaking and standing. 1 mol. $FeCl_3 = 6$ mol. NaF. The $FeCl_3$ solution is made from the commercial article. Determine its content in Fe, and dilute until 1 c.c. = 0.01 gm. NaF.

Technical NaF contains some acid fluoride (NaF,HF) and Na_2SiF_6.

To determine these, dissolve 0.5 gm. in 25 cc. hot H_2O, and titrate with N/ or N/10 NaOH with phenolphthalein indicator. The reactions are:

$$Na_2SiF_6 + 4NaOH = 6NaF + SiO_2 + 2H_2O$$
$$NaF,HF + NaOH = 2NaF + H_2O$$

In this neutralized solution titrate the NaF as above. In another 0.5 gm. of the sample, after adding 0.5 gm. KCl and 20 c.c. alcohol, titrate acidity with N/NaOH and phenolphthalein. This last gives the acidity due to NaF,HF only, the H_2SiF_6 having been eliminated as insoluble K_2SiF_6. From the data obtained the proportions of NaF, NaF,HF and Na_2SiF_6 may be calculated.

Iron — Steel — Ferro-alloys.

Iron Alloys.— Wunder and Stoicoff. (*Ann. Chim. Analyt.*, XVII, 361) Dissolving in H_3PO_4, to which has been added a little H_2SO_4, gives solutions in which Fe may be titrated with standard $KMnO_4$. The H_2SO_4 prevents oxidation during solution, but when used alone does not give accurate results if the alloy is rich in C. In H_3PO_4 solution the C does not prevent accuracy.

Slag in Steel.— Mars and Fischer. (*Stahl u. Eisen*, XXXII, 1557) The Eggertz method is the best, though there is some doubt about complete decomposition of carbides and phosphides. Treat 10 gm. in 50 c.c. ice water with 50 gm. I. After the steel has dissolved, heat on water bath, stirring constantly to remove carbide and phosphide. Then add 200 c.c. air-free H_2O, and let settle. Filter through a Neubauer crucible, and wash the C and slag with dil. HCl till free from Fe, then with H_2O till free from HCl. Dry and weigh. Ignite off C, and weigh again, or determine C.

Ferro Silicon.— Camilla and Pertusi. (*Ann Lab. Chim. Cent. de la Gabelle*, VI, 627) For approximate results that will serve in many cases, treat 0.4 to 0.5 gm. of the pulverized sample in Pt crucible with 20 to 30 c.c. HF and a few drops conc. HNO_3; when the solution comes clear add a little conc. H_2SO_4 and evaporate to dryness. Ignite to constant weight, calculate Fe from the Fe_2O_3, and get Si by difference.

Rarer Metals.

Beryllium Precipitations.—Bleyer and Boshart. (*Zts. anal. Chem.*, LI, 748) The material of the containing vessel makes some difference. Porcelain or Pt are preferable to glass. NH_4OH does not give complete precipitation unless NH_4Cl is present. Boiling out excess of NH_3 gives low results on account of re-solution of some Be. Cold precipitation by NH_4OH in presence of NH_4Cl gives correct results. Wash with H_2O containing a little NH_4OH and NH_4NO_3; ignite and weigh BeO.

Glucinum from Aluminium.— Browning and Kuzirian. (8th Int. Cong. App. Chem., I, 87) The process is similar to that of Gooch for separating Li. $Be(NO_3)_2$ is soluble in anhydrous amyl alcohol, while $Al(NO_3)_3$ is not. Add amyl alcohol to a concentrated solution of the mixed nitrates, and boil out the H_2O. Two treatments are advisable to effect complete separation.

Tungsten and Rare Earths.—Wunder and Schapira. (*Ann. Chim. anal.*, XVIII, 257) From these earths W is separated by fusing with considerable excess of Na_2CO_3 (5 gm. to 0.035 mixed oxides) for an hour, leaching by boiling 20 min. with H_2O, and washing with H_2O containing a little Na_2CO_3. The Th or La or Ce oxides can be washed with 5 percent. HCl; oxides of Di and Er dissolve in dil. HCl and must be re-precipitated by NH_4OH. WO_3 in contact with Er, Ce, or Di oxides is partially volatilized on ignition.

Palladium.—Wunder and Thuringer. (*Zts. anal. Chem.*, LII, 101) Dimethyl glyoxime in alcoholic or HCl solution precipitates Pd yellow, soluble in NH_3, almost completely insoluble in H_2O or dilute acid. The reaction serves especially for separating Pd from Cu or Fe. To the acid solution of 150 c.c. bulk, add the reagent (in large proportions if much Fe is present), let stand on the water-bath for 30 min., filter, etc., finally igniting to metallic Pd for weighing.

Palladium.—Schmidt. (*Zts. anorg. Chem.*, LXXX, 335) To the solution slightly acidified, add α nitroso β napththol, which gives a voluminous red-brown precipitate of Pd $(C_{10}H_6NO_2)_2$. Qualitatively, 0.001 mg. can be detected in 1 c.c. Quantitatively 0.02 gm. Pd was determined accurately in presence of much Rh, and a considerable excess of Pt. Wash with hot H_2O and ignite to metal for weighing.

Industrial Compounds.

Hydrocarbons of the Benzene Series.—(*Ann. Chim. anal.*, XVIII, 230) The test depends on the miscibility with alcohol; 5 c.c. of alcohol will come clear with 5 c.c. of light petroleum, but with xylene, toluene or commercial benzene 10 c.c. of the aromatic hydrocarbon is necessary to clear it. With pure C_6H_6, 15 c.c. will be needed.

Ceresin in Paraffin.—Armani and Rhodans. (*Ann. Lab. Chim. Centr. de la Gabelle*, VI, 109) Dissolve 0.1 gm. of the sample in 10 c.c. of a mixture of equal volumes of absolute alcohol and C_6H_6, by heating. Insert a thermometer, and note the temperature at which turbidity occurs. With pure ceresin the critical temperature is 50° C.; 90 per-percent., 48°; 80 percent., 47°.5; 70 percent., 47°; 60 percent., 44°.5; 50 percent., 43°; 40 percent., 41°.5; 30 percent., 40°; 25 percent., 38°; 20 percent., 36°.5; 10 percent., 30°; 5 percent., 27°. For paraffin alone, the temperature may vary from 20° to 28°, but is usually 25°. The method has been devised mainly for testing candles.

Sulphur in Illuminating Oils, etc.—Conradson. (8th Int. Cong. App. Chem., I, 133) By "lamp" methods—burning in a lamp, and passing the products of combustion through a known amount of standard Na_2CO_3 solution, and then titrating back, or oxidizing with Br and precipitating with $BaCl_2$, dissolved S or that in volatile S compounds may be determined. Sulfates, or sulfonates are retained by the wick, in which the total S can be determined by disintegrating with conc. HNO_3 after adding 0.2 gm. Na_2CO_3, then adding $Mg(NO_3)_2$ and heating gradually up to the temperature of ignition, until all C compounds are destroyed, the product being handled by well known methods. Or if a separate

determination of sulfonates is desired, the wick is boiled with $Ba(OH)_2$, diluted, and filtered, and the filtrate containing only sulfonates is oxidized by Br and evaporation with HNO_3, etc.

Barium Aluminate.— Vandevelde. (*Bull. Soc. chim. Belge,* XXVI, 319) This article is sold for purification of boiler feed-water. Its value depends upon the amount soluble in H_2O. 10 gm. should be extracted with 800 c.c. cold H_2O. Hot water in smaller amount gives unsatisfactory results. Alkalimetric tests give indistinct end reactions with the solutions. The ordinary gravimetric estimation of Ba and of Al are necessary. The composition was found to vary from $5Al_2O_3,3BaO$ to $10Al_2O_3,7BaO$.

Copper Sulfate for Agricultural Purposes.— Zecchini. (*Ind. Chim.,* XII, 182) With a mixture of $CuSO_4$ and $Na_2S_2O_3$ in presence of NH_4CNS, the $CuSO_4$ is reduced at the expense of $Na_2S_2O_3$ and precipitated out as $Cu_2(CNS)_2$. By using a known amount of $Na_2S_2O_3$ the excess can be titrated with standard I solution. A solution should be made containing 19.878 gm. $Na_2S_2O_3$ and 8 gm. NH_4CNS per litre. To 60 c.c. of this, add 1 gm. of the salt dissolved in 50 c.c. H_2O. Mix thoroughly, then add starch, and titrate with standard I solution. The usual impurities of commercial $CuSO_4$ do not interfere.

Potassium in Fertilizers — Perchlorate Method.— Strigel and Dodt. (*Lander. Vess. Stat.,* LXXVIII, 179) Boil 10 gm. of the sample with about 300 c.c. H_2O and 2 c.c. HCl (Sp. Gr., 1.125). Precipitate out H_2SO_4 by addition of $BaCl_2$, avoiding any large excess. Cool, dilute to 500 c.c. and filter. Take out 25 c.c. (= 0.5 gm.) and evaporate it with 10 c.c. of 22 percent. $HClO_4$ to a decided syrup. Treat in the usual manner, drying the $KClO_4$ at 180° for weighing.

Free Acid or Free Base in Commercial Aluminium Sulfate.— Ivanof. (*J. Soc. Phys. Chim.* R., XLV, 57.) Neutral salts of Al are precipitated by boiling with $K_4Fe(CN)_6$. The difficulty is that the precipitation of Al_2O_3 is incomplete below 85° and above that temperature H_2SO_4 decomposes the $K_4Fe(CN)_6$. This is met by adding $BaCl_2$ to make HCl the free acid.

Dissolve 1 gm. of the sample in 50 c.c. H_2O. Heat to 85°; then add quickly 12 c.c. $K_4Fe(CN)_6$ solution (1 in 12); follow this immediately with 10 c.c. 10 percent. $BaCl_2$ solution. Stir, and pour into a 100-c.c. flask. Fill to about 0.25 c.c. above the mark (allowance for bulk of precipitate), agitate, and let stand for an hour. The solution should then have become clear. Pipette off 25 or 50 c.c. of the clear solution and titrate with N/10 NaOH and methyl orange indicator, which gives the free acid in the sample. If the sample is basic, add 2 c.c. N/2 HCl to the solution after dissolving 1 gm. of the sample; proceed as before, and allow for the HCl added in calculating the results.

Mixed Acids in Nitrating Glycerin, Cellulose, etc.— Finch. (*Zts. Schiess. u. Sprengst.,* VII, 337) Determine total acidity by N/10 $Ba(OH)_2$ with phenolphthalein indicator. Heat to boiling, and filter off $BaSO_4$, assisting by use of cellulose. Heat filtrate to boiling, and

titrate with neutral N/5 K_2CrO_4 solution added slowly, that the $BaCrO_4$ may settle out satisfactorily. The end point is persistence of chromate color in the solution. This gives HNO_3 and HNO_2 together. Determine HNO_2 by titration of another portion with standard $KMnO_4$.

Free Lime in Cements.— McFarland and Hadley. (8th Int. Cong. App. Chem., V, 83.) Shake 3 gm. of the sample for an hour or more with 21 c.c. absolute alcohol, 30 drops para cresol, and 0.5 c.c. H_2O. Filter, and wash until the washings are no longer red. Evaporate the filtrate and ignite, weighing as CaO.

Cements.— Hentschel. (*Chem. Ztg.*, XXXVI, 821) Grind 1 gm. with 20 to 30 c.c. of 80 percent. acetic, and heat on the water bath until decomposed. Heat to boiling, add 20 c.c. hot H_2O, and HNO_3 little by little until the red ferric color disappears. Boil a little longer, filter, and wash by decantation, using H_2O acidified with HNO_3. For sulfates, boil, add a little solid $BaCl_2$, and after 5 to 10 min. add HCl. Boil some minutes longer, then allow to stand a short time, and filter off the $BaSO_4$.

Hydrogen Gas — Qualitative.— Pereira (*Anales Soc. Espan. fis. quim.*, X, 370) Mix 2 c.c. saturated phosphomolybdic solution with 3 c.c. H_2O and 1 c.c. of 1 percent. $PdCl_2$ solution. Heat to 80° C. and pass a rapid current of the gas: Blue coloration indicates H. Or add 2 drops of 1 percent. $PdCl_2$ solution to 2 c.c. of a mixture of equal parts of glacial acetic and 10 percent. Na_2WO_4, and pass the current of gas. The reaction also is blue coloration.

Gas analysis — Absorption of Acetylenic and Ethylenic Hydrocarbons. — Lebeau and Damiens. (*C. Rend.*, CLVI, 557) For the acetylenic hydrocarbons the reagent consists of 25 gm. HgI_2 with 30 gm. KI in 100 c.c. H_2O. When used, add a fragment of KOH. The reagent will absorb 20 times its volume of C_2H_2, giving a white precipitate. For olefines, the absorbent is a 1 percent. solution of V_2O_5 in conc. H_2SO_4, or a 6 percent. solution of $UOSO_4$. Either will absorb 150 times its volume of C_2H_4 without affecting the CO that may be present.

White Phosphorus in Matches.— Schröder. (*Ark. K. Gesundht.*, 1913, 44) Treat with a little benzol, and then saturate a strip of filter paper with the extract. Suspend the paper inside of a glass tube, and pass a current of air heated to 40° or 50°. In a dark room the paper will show luminescence if even so little as 0.01 mgm. white P is present. Other varieties of P do not show this reaction.

Perborates — Available Oxygen.— Litterscheid and Guggiari. (*Chem. Ztg.*, XXXVII, 690) Available O can be determined by loss of weight when 2 gm. are mixed with 2 gm. MnO_2 and treated with dil. H_2SO_4 (25 percent.) in a CO_2 apparatus. Half the loss is the available O. If carbonates are present, the CO_2 must be expelled by treatment with the H_2SO_4, before adding the MnO_2.

Paints and Pigments.— Kohn-Abrest. (*Ann. Chim. anal.*, XVII, 249) Pigment can be tested directly. If there has been admixture of oil, etc., mix with 15 percent. solution of NH_4NO_3 and burn off cautiously.

Shake 0.2 gm. of the pigment with about 12 c.c. of a mixture of equal volumes of NH_4OH, 20 percent. NH_4Cl, and 20 percent. $(NH_4)_2CO_3$.

This will dissolve out all ZnO. Tests may be applied to the residue; e. g., if completely soluble in dilute HCl, $BaSO_4$ is absent, etc. The method is inapplicable with lithopone or where ZnS is present.

Iodine in seaweed.— Knudsen. (*Chem. Eng.*, XVII, 119) The CCl_4 method (*vid.* QUARTERLY, XXXIV, 54) is adversely criticized. The method preferred is essentially Grögers: Extract 20 gm. of the ash with boiling H_2O, and wash free from I. Extract and washings are brought to 500 c.c. Boil 100 c.c. and run in $KMnO_4$ until the pink color persists. KIO_3 is formed, and MnO_2. Add alcohol drop by drop to destroy excess of $KMnO_4$, filter off MnO_2, and wash cold. Then add 10 to 15 c.c. of 5 percent. KI, acidify with H_2SO_4, and titrate with $Na_2S_2O_3$. $KIO_3 + 5KI + 3H_2SO_4 = 3K_2SO_4 + 3H_2O + 6I$. I found is divided by 6.

Bromine — Delicate reaction.— Guareschi. (*Giorn. farm. Chim.*, LXI, 392) Dissolve 0.1 to 0.2 gm. of the substance in a few drops of H_2O, add 4 to 5 c.c. of 15 to 25 percent. CrO_3, and suspend in the neck of the retort a paper saturated with Schiff's reagent for aldehydes. (Fuchsin decolorized by $NaHSO_3$ and HCl). If Br is present, the paper takes an azure violet coloration. Reaction occurs in the cold, but more rapidly by heating. The substance formed is insoluble in H_2O but somewhat soluble in alcohol, C_6H_6, and CCl_4.

Deniges (*C. Rend.*, CLV, 721) describes essentially the same test applied in another way. Fuchsin bisulfite is made by adding 10 c.c. of $NaHSO_3$ solution (30 to 33° Be.) to 1 litre of 0.1 percent. fuchsin; stand 5 min., and then add 20 c.c. conc. HCl. Let stand a couple of hours before using. For a test use 2 c.c. of this solution, 2c.c. H_2O, and 1 c.c. chloroform. Mix, then add solution to be tested, and shake. If Br is present, the chloroform takes an amethyst color.

FOODS — SANITATION.

Ammonia in Effluents and Sewage.— Krapivin. (*Zts. anal. Chem.*, LII, 198) Put 100 c.c. of the water in a 200-c.c. flask; add 10 c.c. of 10 percent. $BaCl_2$, then 10 c.c. N/5 NaOH, and a little phenolphthalein. Dilute to the mark, and mix well. Filter, and neutralize 100 c.c. of the filtrate with N/10 HCl. Then add 5 c.c. of 40 percent. formaldehyde and titrate with N/20 NaOH. Add another 5 c.c. of the formaldehyde and titrate again. The last titration shows the acidity of the formaldehyde used. Deducting this from the figure for the preceding titration gives the number of c.c. due to reaction between the formaldehyde and NH_3 present.

BOOK REVIEWS.

Analytical Mechanics. By H. M. Dadourian, M.A., Ph.D. Cloth; 6x9 in.; 353 pp.; 148 figs. D. VanNostrand Co., New York. Price $3.00.

This text is based on the work of the Junior class in the electrical engineering department of the Sheffield Scientific School, and is written primarily for use with students of engineering who have already studied calculus and physics. It includes also other material than that usually given such students, so as to be suitable also for those not studying to be engineers.

The author has attempted to introduce into this text some new methods of treatment. He emphasizes especially his aim to combine with "economy of thought" a certain "efficiency in thinking," by which he means the presentation of the fundamental principles of the subject in a simple form from which the more complicated relations may be deduced in a short yet logical manner. To this end, and for certain other theoretical reasons, he bases the entire treatment on the law of equality of action and reaction, the ordinary form of Newton's second law being treated as a consequence of this.

The study of vectors and other elementary properties is well treated in the first chapter, vector notation and vector equations being freely used. Statics occupies the following two chapters, the equilibrium of flexible cords and the friction of ordinary surfaces and especially of various types of journals being discussed in some detail. Following a chapter on general kinematics is a long chapter treating of the dynamics of a particle, based on the idea of kinetic reaction. Chapters on centers of mass and moments of inertia and chapters on work and energy follow in due course. The remaining two-fifths of the book comprises chapters on the potential function, uniplanar motion, and linear and angular impulse and momentum; a chapter on the central motion of a particle; and a chapter on periodic motion. This last chapter is largely taken up with mathematical discussions of various types of pendulums, with a fair treatment of simple harmonic motion.

The book contains numerous problems, illustrating the various principles. These are for the most part of the type to be found in such texts, although the author has made use of a great many problems which are not at all suitable for the engineering student. The illustrations are excellent and greatly aid in reading the text.

For the ordinary student in engineering this text is entirely unsuitable. The contents and manner of presentation are not such as so to train the student, that he can apply the principles of mechanics logically and directly to his engineering problems. The space devoted to statics is too limited, and the character of the problems not sufficiently practical. For example, the idea of stress is neglected, and the study of structures is omitted. The subject of dynamics, although treated in much greater

detail, is open to a similar criticism. Little attention is paid in the text to the technical side of the subject, and only a few of the problems set for solution are suitable for the engineering student. Too much space is devoted to central motion and problems of that character. In general this text resembles in its content the more or less numerous non-technical works used in connection with classes of non-engineering students.

The adoption of the law which states that the sum of all the actions to which a body is subject is always zero, as the basis of the entire subject of mechanics will undoubtedly recommend itself to many as having the advantage of simplicity. The author's reasons for its use are, however, based on certain technical objections to the ordinary form of Newton's laws, which objections would not be appreciated by the students for whom this text is designed. As treated in this text this law does not result in any great simplification or in any "economy of thought," except for the student whose chief aim is the memorizing of formulas or methods of solution with the minimum of mental effort. The development of the more complex laws of mechanics from the fundamental law is incomplete and illogical, so that these must be taken rather as a series of disconnected relations based on distinct experiments, or as a set of unproven formulas.

The fundamental law is first stated in section 24, following the statement of Newton's law of the equality of action and reaction as though it were another form of this law, which is, however, quite distinct in its meaning. Furthermore, the author gives no definition of the term "action," which is used throughout the text, and hence the meaning of the law is not clear. In the application of the law to the motion of rigid bodies two types of action, linear and angular, are distinguished, but again the definitions are incomplete, the whole discussion being based on an inaccurate treatment of general plane motion. The relations between the different types of motion and the force systems producing them are stated in section 181 as extensions of the general fundamental law, but inasmuch as they are not the result of a logical deduction from the laws for the motion of a particle they must be considered as based on distinct but inconclusive experiments. It would be of interest in this connection to see how the author would treat by this principle the motion of an unbalanced fly-wheel.

This same lack of logical connection is seen throughout the text Added to it is a laxness in the definitions of terms used. Force is defined in terms of "action," but in reality helps to define the latter. The term "stress" is used freely, but never defined or explained. The term "pure rotation" is used in section 42 without definition, and the derivation of the important conclusions based thereon cannot be understood. The definition of moment of force in section 47 is derived in a very unsatisfactory manner. Further instances might be cited.

As a text for engineering students this book is not at all suitable, and it is not of sufficient merit to recommend itself for use in a general course in mechanics. It is of interest, however, because of the unusual manner in which the author has attempted to develop the subject of mechanics.

HAROLD W. WEBB.

Electrical and Magnetic Calculations. By A. A. Atkinson, Professor of Physics and Electrical Engineering, Ohio University. Cloth; 5 x 7½ in.; 310 pp.; 45 figs. D. VanNostrand Co., New York, 1913. Price $1.50.

That Prof. Atkinson's little book fills the needs of certain classes of workers is shown by the fact that the present edition is the fourth since the book first appeared in 1902. The title well describes its contents. The book does not pretend to derive logically the theory of electricity and magnetism but does present the more elementary theory in a sort of hand-book style, and then supplements it by numerous problems; the collection of problems constitutes by far the most valuable portion of the book, in our opinion.

The treatment of the theory involved in the various problems is very superficial and unsatisfactory. This is due to the author's attempt to cover so much ground in such a limited space; probably not more than one hundred pages are given over to a logical development of the formulas used in the problems, and when it is observed that the problems cover all sorts of circuits, both for continuous- and alternating-current generators and motors, single-phase circuits and polyphase circuits, transmission lines, etc., it is evident that the theoretical treatment must be of the most elementary character.

On the whole, the problems are well selected and they should be of service to any teacher of elementary electrical theory. We, however, think it inadvisable to carry out voltage calculations to five or six significant figures, when the "practical man," for whose benefit the book is written, is capable of measuring it only to the third, or at best, the fourth significant figure. The solution of a problem in transformer design which recommends the use of a No. 0 and a No. 00 wire, wound in parallel, will not appeal strongly to the practical designer. The utility of a chart for calculating wire sizes on a 55-volt distribution system is open to question; 55 volts is not used today as a standard. Transformers with a secondary voltage of 52 volts, frequencies of 125 cycles, the monocyclic system, etc., are features of the problems which might well be eliminated. The rating of alternating-current machinery in kilowatts is not in accordance with modern practice. The author's symbols are not in accordance with those used in standard texts and his definitions are somewhat loose. Thus, one might suppose, from his definition of self induction, that a coil, the magnetic circuit of which contains iron, has no such property as self induction. Instead of speaking of vectors in developing the alternating-current theory, the author uses such expressions as "the *capacity and inductance lines* are opposed to each other," etc.

In spite of such defects as are noted above the book should be useful because of the many and varied problems which are given and solved.

J. H. M.

Experiments for Students in General Chemistry (Shorter Course). By Edgar F. Smith and Harry F. Keller. Cloth; 4½ x 7 in.; 54 pp.; illus. P. Blackiston's Son & Co., Philadelphia, 1913. Price $0.60.

This short manual is a condensation of a more extended volume over

the same subject, and is designed for beginners in chemistry. The course consists of a series of general introductory experiments followed by the usual reactions of metallic radicals. The lack of illustrations to the text will be felt by the student. Frequent questions are introduced into each chapter of the work, and the general revision at the end of each series of experiments will be of great assistance. H. B. N.

Laboratory Experiments in General Chemistry. By H. B. North. Cloth; 5 x 7½ in.; 205 pp.; 36 figs. D. Van Nostrand Co., New York, 1913. Price $1.00.

The volume contains a complete series of experiments over the field of simple introductory work and qualitative analysis. The large variety of experiments included are graduated in difficulty, with the intention of making the book meet the needs of various classes of students, so that the volume is at the same time useful to the beginner in chemistry and to the student with some degree of previous training. The illustrations to the text and the appendix on chemical arithmetic will be found helpful to students employing the manual. H. B. N.

Physical Measurements. By A. Wilmer Duff and Arthur W. Ewell, Professors of Physics, Worcester Polytechnic Institute. Cloth; 5 x 8 in.; xii + 244 pp.; illus. Third Edition. P. Blackiston's Son & Co., Philadelphia, 1913. Price $1.50 net.

On inspecting the table of contents of the students' laboratory manual we see that it contains a General Introduction; seventy-two exercises grouped under the headings: Mechanics, Heat, Sound, Light, Electricity and Magnetism; and twenty-four tables.

In the introduction are given general laboratory directions and a short discussion on "errors." Only eight pages are devoted to the latter which seems unfortunate in view of the fact that in four or five times that amount of space this important subject might have been treated quite satisfactorily. In striving for brevity the authors also have modified some of the well known rules for the computation of errors in such a way that they no longer conform with the theory. The rules on the plotting of curves are short and to the point.

Each group of exercises is preceded by a short description and introduction to the use of the most fundamental instruments used therein. These together with a few theoretical considerations made it possible to put the exercises themselves into a more condensed form.

The exercises are well chosen and numerous enough to make a first-rate list to select from. The statement of the exercise, which is in most cases accompanied by a clear diagrammatic cut, is in general quite brief but is preceded by a list of references, at least one of which the student should be required to look up. The questions after nearly every exercise are a very good feature. The tables at the end of the volume form a valuable addition.

As a whole the book is well adapted to be taken as the basis of a thorough laboratory course of from one to two years' duration.

M. F. WEINRICH.

Igneous Rocks: Vol. II: *Their Composition, Texture and Classification, Description and Occurrence.* By Joseph P. Iddings. Cloth; 6 x 9 in.; 685 pp.; 8 maps, 20 figs. John Wiley & Sons, New York. 1913. Price $6.00.

The second volume of this splendid work, devoted chiefly to rock description and occurrence, has just appeared. The first volume, devoted more particularly to composition, texture, and classification, was issued in 1909, and this was followed by a correspondingly thorough treatise on "Rock Minerals." This series of volumes on minerals and rocks is undoubtedly the best treatment of the whole subject of rock study published in the English language. The mineralogic side of the subject is thoroughly treated by other good textbooks, whereas there are few competitors on the petrologic side proper; hence the new volume is a most welcome addition to the equipment of American students in this line.

The particular purpose of Volume II we are told in the preface is "to present a brief sketch of the distribution of igneous rocks throughout the world, so far as known, in order to lay the foundation for a study of possible petrographical provinces."

The book contains 674 pages and index. Part I is devoted to description of igneous rocks, introduced by a discussion of the scope and method of description. Then follow descriptions of rocks representing the known mineralogic and textural variations, grouped under six mineralogic divisions, the first of which, for example, includes rocks characterized by preponderance of quartz. Others include rocks characterized by feldspars with and without quartz, feldspathoids, feldspars with feldspathoids, and ferro-magnesian ("mafic") minerals, making six divisions in all.

There are 342 pages devoted to the treatment of this series of groupings. Part II is devoted to occurrence of igneous rocks throughout the known world.

This is a book for advanced students and investigators in petrology. It is an organized summary of the literature of the science with respect to description and occurrence and its chief value lies in the thoroughness of the work and its reliability as a book of reference.

CHARLES P. BERKEY.

General and Industrial Organic Chemistry. By Dr. Ettore Molinari. Translated from the second enlarged and revised Italian edition by Thomas H. Pope. Cloth; 6 x 9½ in.; xix + 770 pp.; 506 illus. P. Blackiston's Son & Co., Philadelphia. 1913. Price $6.00 net.

There has always existed more or less of a gap between the applied and theoretical sides of organic chemistry as presented by our textbooks, most of which emphasize either one side or the other. In this book the author has succeeded, in an admirable way, in combining these two parts of the field so that the student can readily see the theoretical back-ground of organic chemistry as used in the industries.

By means of this presentation, the compounds and reactions which are of most practical significance, as well as those of more theoretical interest, are easily pointed out. In addition, statistical data have been

added so that the student may be in a better position to judge the relative commercial importance of many organic products.

At the present time when courses in chemical engineering are becoming so popular in many of our technical colleges, a textbook of this kind ought to meet with considerable interest. The book is also well suited for the reference library of any chemist, whether technical or teacher. In this respect, however, it must be said that too few references are given to the literature.

J. M. NELSON.

SUMMER ACTIVITIES.

CAMP COLUMBIA.

The organization of the Summer School of Surveying at Morris, Conn., which started on May 3 and closed on Sept. 13, was in charge of the writer, assisted by Elmer Roberts, C. E., '13, in charge of highway survey and instruments and supplies; W. H. Shearman, E. M., '09, in charge of mine claim; R. W. Briggs, C. E., '11, in charge plane table and topographic surveys; A. D. Duffie, C. E., '13, in charge of pacing survey; G. R. Genung, C. E., '13, in charge of repetition survey and leveling; G. D. Peet, C. E., '13, in charge of solar work and city surveys; W. W. Steinbruch, C. E., '13, in charge of farm survey and meteorology. The work in geodetic surveying was, as usual, conducted by the Department of Astronomy, Prof. Harold Jacoby in charge. This work was given in connection with the hydrographic survey and the field instruction was in charge of Wm. Bowie, Inspector of geodetic work, U. S. C. and G. S. This is the second year that the Department of Astronomy has been able to get Mr. Bowie's services for this work, and it was carried out in the same thorough manner as in 1912. Mr. Bowie was assisted by Messrs. C. A. Mourhess and E. F. Church of the U. S. C. and G. S. E. C. Hawley, A.B., acted as Y. M. C. A. secretary during the major part of the session and the commissary was in charge of D. T. Jones, A. B., Colgate, '13.

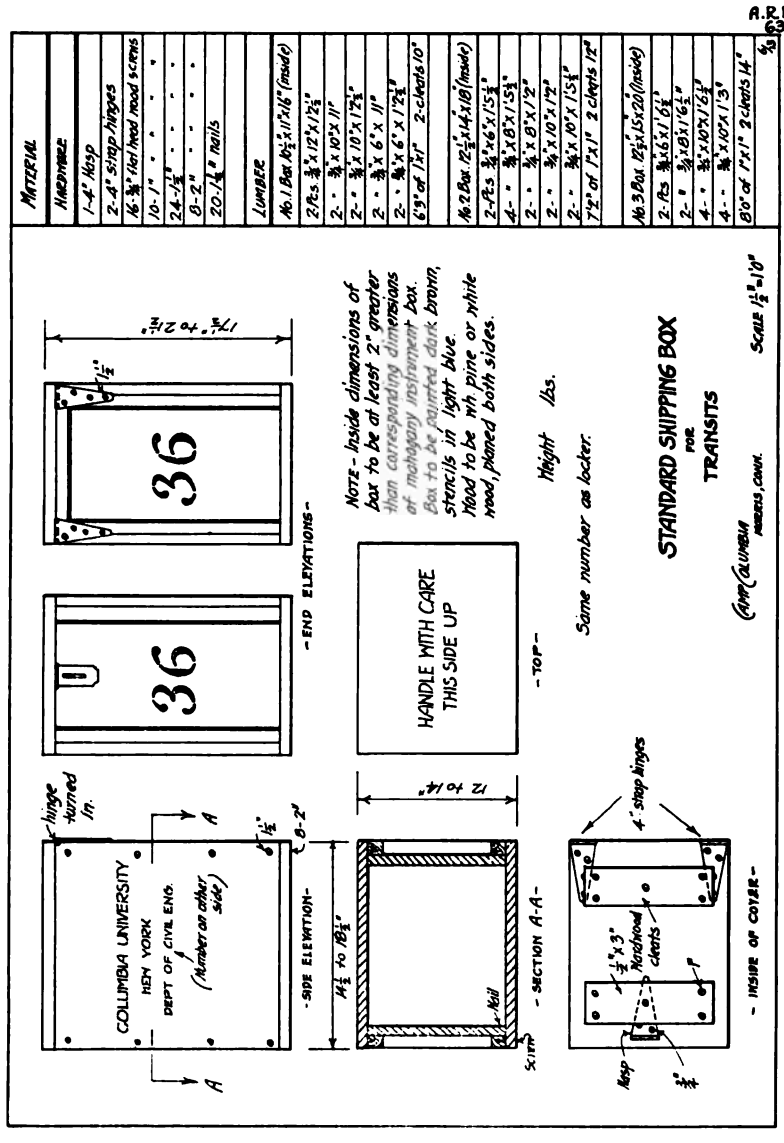
Among those who visited and inspected the Camp during the summer were Dean F. A. Goetze, Prof. and Mrs. Wm. H. Burr, Prof. and Mrs. H. S. Munroe, Prof. S. O. Miller, and Dr. C. W. McMurtry, Chas. S. Danielson, Bursar, B. B. Lawrence and John B. Pine, Trustees, and the following alumni: R. S. Baylis, '06, H. T. Cole, '11, F. Leiser, '11, R. Van A. Norris, '85, M. A. Van Siclen, '06, and Wm. Wilson, '08. We were also pleased to welcome to the Camp Dr. Luther, President of Trinity College, Chas. Derleth, Dean of the College of Engineering, University of California, and Prof. H. C. Tracy, of Sheffield Scientific School.

Student activities at the Camp were well taken care of although we did lose the annual baseball game with Litchfield, by the close score of 6–7. A glee and mandolin concert was given at Morris on June 6, on June 21 the crew-night feed and bonfire was held, the fire being started by Prof. E. B. Lovell, who was spending a few days at Camp at that time; and on Aug. 9 the baseball team defeated the faculty team of Camp Wonposet, a near-by boys' camp, by score of 17–2. An effort was made to persuade alumni to come back to the Camp for the Litchfield game and railroad dinner, but due to the late date at which invitations were sent out only a few responded. The game and dinner will be held on August 29 next year and it is hoped that a large number will be able to be present.

The weather report of Mr. Steinbruch shows that the average temperature during the past summer was some 3° above normal, and the total rainfall during the session about the same as last summer, 8.87 inches. As might be expected from these figures, the number of clear days was

large, 82 out of 115, and weather conditions in the main were very favorable for field work.

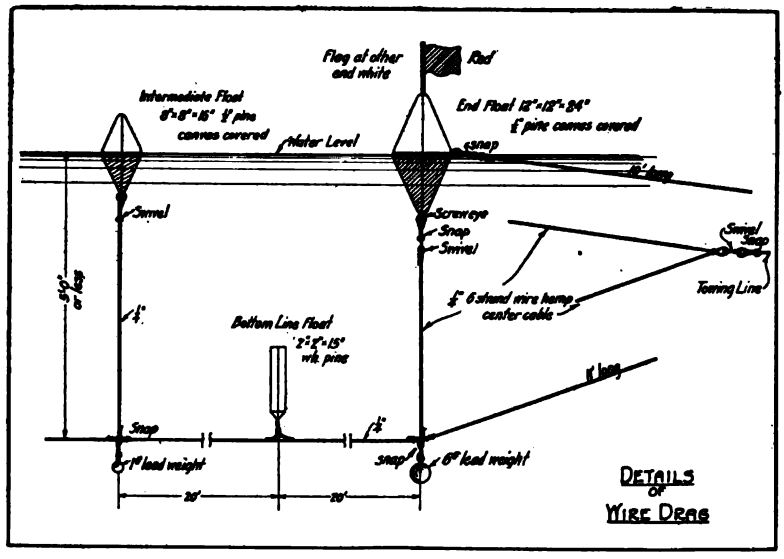
The attendance was smaller than usual, due to the small freshman


A.R.13
MATERIAL
HARDWARE
1-4" Hasp
2-4" strap hinges
16-¾" flat head wood screws
10-1" " " "
24-1½" " " "
8-2" " " "
20-¼" nails
LUMBER
No.1 Bot. 11½"x11/16" (inside)
2 Pcs ⅞"x12"x12½"
2 - ⅞"x10"x11"
2 - ⅞"x10"x12½"
2 - ⅞"x 6"x 11"
2 - ⅞"x 6"x12½"
6'9" of 1"x1" 2 cleats 10"
No.2 Box 12½"x14"x18" (inside)
2 Pcs ⅞"x6"x15½"
4 - " ⅞"x8"x15½"
2 - " ⅞"x 8"x12"
2 - " ⅞"x10"x12"
2 - " ⅞"x10"x15½"
7'2" of 1"x1" 2 cleats 12"
No.3 Box 12½"x15"x20" (inside)
2 Pcs ⅞"x6"x1'6½"
2 - " ⅞"x8"x1'6½"
4 - " ⅞"x10"x1'6½"
4 - " ⅞"x10"x1'3"
8'0" of 1"x1" 2 cleats 14"
36
- END ELEVATIONS -
NOTE - Inside dimensions of box to be at least 2" greater than corresponding dimensions of mahogany instrument box. Box to be painted dark brown, stencils in light blue. Wood to be wh. pine or white wood, planed both sides.
HANDLE WITH CARE THIS SIDE UP
- TOP -
Height 12½.
Same number as locker.
STANDARD SHIPPING BOX FOR TRANSITS
(AMERICAN) MADE BY KEUFFEL & ESSER CO. HOBOKEN, N.J. NEW YORK CHICAGO SAN FRANCISCO MONTREAL
SCALE 1½"=1'0"
hinge turned in.
COLUMBIA UNIVERSITY
NEW YORK
DEPT. OF CIVIL ENG.
(Number on other side)
- SIDE ELEVATION -
- SECTION A-A -
Nail
Screw
4" strap hinges
1"x3" Hardwood cleats
Hasp
- INSIDE OF COVER -

class and the exceptionally small mining class; 234 different students reported during the summer, the maximum attendance being 99, average 74, and minimum 53. The number of students taking each course was as follows: Course 15, 144; course 25, 36; course 27, 30; course 26, 28;

Geodesy, 24; course 28, 31; course, 71, 27. Only 36 men failed to complete the entire course in which they were working.

The new work accomplished during the summer included a careful revision of the method of handling instruments and supplies, and the construction of new shipping boxes for the instruments. These boxes are of a rather unusual design and have been found to be very satisfactory, as they are easily handled and can be packed very closely for shipping. A drawing of a typical box is shown herewith. A blue print room has also been equipped in the attic of the office building. The notes and instructions for all the surveys, covering over 300 pages of typewritten matter and drawings, was also completely revised and rewritten. Particular attention should be called to the highway survey. This work was formerly known as profile leveling, but has been changed

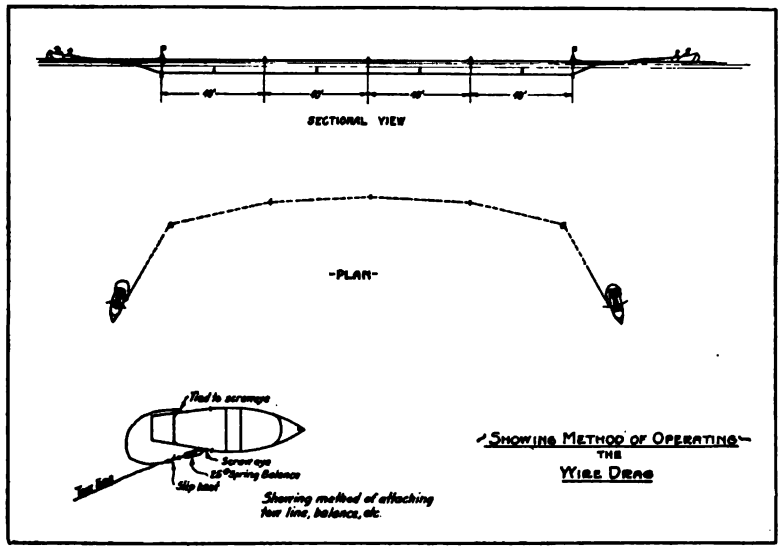


into a preliminary survey for highway improvement, and includes proposed changes in alignment as well as grade. It is an extremely important and valuable exercise in work of this character and particularly in the making of preliminary estimates of quantities and costs.

Complete instructions were also prepared for the hydrographic work, comprising blank forms for the various parts of the work, particularly the measurement of discharge by floats, and rating and discharge blanks for current-meter work. Although the only available streams near Camp were very low last summer, some current-meter work was attempted and a few satisfactory observations were obtained.

A new piece of apparatus was made by the instructing force for use in the hydrographic survey, but due to lack of time was not used by the students. This consisted of a modification of the long-wire drag used by the Government engineers in locating pinnacle rocks. It should be explained that pinnacle rocks or small ledges often escape notice in

sounding by the ordinary method, and the long-wire drag has been developed in order that areas in which such rocks may occur can be swept over and these rocks located and charted. "A Description of the Long-Wire Drag," a special publication of the Department of Commerce and Labor, by N. H. Heck, 1910, describes this apparatus, which is sometimes made one mile and over in length. For the work on Bantam Lake, a much smaller apparatus was required and the final design is shown in the sketches herewith. The buoys were made of half-inch pine boards covered with canvas. Actual tests showed that a pull of only 8 or 10 lb. was required to move this drag through the water. When any rock that comes within a distance of the surface less than the depth for which the bottom wire is set is encountered, an indication will be given in one or more of the following ways. If the rock slopes gently upward there may be a slight increase in the tension on the balances, but the principal



indication will be due to the raising of the bottom wire and consequent release and overturning of the nearest buoy. On sharper projections, the drag will catch and the tension increase rapidly, also the curve of the drag will be broken and the point of obstruction shown by the fact that the buoys no longer "line up" on a smooth curve. This adaptation of the coast survey apparatus would be useful in navigation surveys of smaller harbors, streams, and lakes and may be of interest to some readers of the QUARTERLY.

J. K. FINCH.

DEPARTMENT OF GEOLOGY.

The summer field work with the third-year students in the School of Mines and the graduate students was given with Kingston, N. Y., as headquarters, the first week in June. The party numbered fifty. All

were greatly benefited by the study of the remarkable folds and faults in this old district famous for the production of natural-rock cement.

In the regular Summer Session Professor Grabau gave courses in stratigraphical geology and palæontology. The work was successfully conducted and as a result several of the students have remained for further work during the regular year. Minor courses in related subjects were taught by Prof. A. C. Boyle, Jr., of Wyoming State University, and by Mr. F. E. Burr and Miss O'Connell of Columbia University.

Professor Grabau has just brought out an important work of 1150 pages upon the "Principles of Stratigraphy." The book covers much of the instruction given to advanced students in the last five or ten years and will serve as a text-book in some of our higher instruction. Professor Grabau has also issued the following two important papers: "Ancient Delta Deposits of Eastern North America," in the *Bulletin* of the Geological Society of America, and "Palæontology of the Dundee Formation in Southern Michigan," from the Report of the State Geologist of Michigan.

Professor Johnson gave courses in physiography in the Summer Session, which were well attended. He also provided large general audiences with popular lectures on attractive topics in his special line of work. He has continued the preparation of his report upon the stability of the Atlantic Coast in recent times, a valuable contribution which is being prepared with the support of the Shaler Foundation at Harvard University.

Professor Berkey continued work during the summer upon his reports for the State Geologist upon the Tarrytown and West Point Quadrangles. He interrupted these by attending the International Geological Congress which met in Toronto, Canada, on August 7. Before the meeting, Dr. Berkey took part in a very attractive excursion across the ancient formations of Eastern Ontario. Subsequently he visited the asbestos region of Quebec. Valuable collections for the equipment of the department were obtained by him. Dr. Berkey's many friends among the alumni will be gratified to know that at the opening of the year the Trustees promoted him to the grade of Associate Professor. He has continued his work as consulting geologist to the Board of Water Supply of New York City.

Professor Kemp also attended the Geological Congress. Before the sessions he took part in an excursion to Sudbury, Cobalt, and Porcupine, collecting in each mining camp valuable additions to the equipment of the department. He also was a member of a party which visited the interesting exposures in the vicinity of Montreal. Igneous rocks of unusual character are here developed. Just before the Congress opened in Toronto, and while the delegates were in Montreal, McGill University held a special convocation at which the honorary degree of LL.D. was bestowed upon five delegates to the Congress. They were in a way representative of five nationalities, and were: Professor Helge Baeckstroem, of the University of Stockholm, Sweden. Professor Alfred Bergeat, of the University of Königsberg, Germany. Professor Alfred Harker, of Cambridge University, England. Professor J. F. Kemp, of

Columbia University. Professor Alfred Lacroix, of the Jardin des Plantes, Paris.

Among the sessions of the Congress in Toronto a special afternoon was devoted to the discussion of the persistence of ore in depth. The exercises were opened by a paper by Prof. Kemp, devoted to this important topic to the mining industry.

The department has been able to place its graduate students of last year as follows: Mr. F. F. Hintze, who received his Ph.D. at Commencement, is now Assistant Professor of Geology in Lehigh University. Mr. Charles R. Fettke, who should receive the Ph.D. degree in January next, is Assistant Professor of Geology in the Carnegie Institute of Technology, Pittsburg, Pa. Mr. G. J. Mitchell entered the Geological Survey of the State of Oregon in June, and becomes an instructor in the State University with connections on the Survey. The U. S. Geological Survey claimed Mr. Ralph Howell and Mr. T. Y. Wang.

The department opened the current year with a very gratifying number of graduate students — rather more, in fact, than have ever been registered before. The custom is growing for mining engineers who have had some years in practice to return for a year's work in geology.

DEPARTMENT OF METALLURGY.

The Summer field work for 1913 consisted of visits to various metallurgical plants around New York, during which the students were accompanied by one of the professors of the department. The class inspected the works of the Nichols Chemical Co., at Laurel Hill, L. I., where they were shown the sampling, smelting, converting, and copper casting operations, although, as usual, they were not allowed to visit the electrolytic plant. The class then went to Newark, where the works of the Balbach Smelting & Refining Co. were seen. They then spent two days at Chrome, N. J., in the enormous electrolytic refinery of the U. S. Metals Refining Co., where electrolytic refining on the largest scale was seen, and the practical points in connection with the operation were observed by the students. A most interesting visit was paid to the Crucible Steel Co.'s plant at Newark, where the new installation of an open-hearth steel furnace and an electric furnace for super-refining were carefully examined. At the Dixon Crucible Works, in Jersey City, the preparation of material for manufacturing crucibles and similar vessels was noted.

On these trips, the class was composed not alone of metallurgists but of some mining engineers and others who desired to make up metallurgical field work. After this the class of special metallurgists started for the West, stopping first at Trenton, where the large casting and annealing plant of the Mott Iron Works was visited under the supervision of Prof. Walker. From this point, after receiving final instructions, the men started off for themselves, spending two weeks in the iron and steel districts around Pittsburg, then travelling west to the U. S. Steel Corporation's plant at Gary, Indiana. At Chicago, the men split into two squads — one going down through the zinc and lead districts of the Middle West, the other going to Colorado, where the lead

and zinc smelteries were inspected. Altogether the summer class in field metallurgy had a very interesting and beneficial experience.

At the annual meeting of the American Society for Testing Materials, Wm. Campbell, chairman of the committee on non-ferrous metals and alloys, presented the report of this committee covering the work of the year, and including two new standard specifications for Lake copper and electrolytic copper. Both of these specifications were adopted.

Prof. Walker did not go west with the class this year, but instead paid a short visit to Newfoundland, stopping at Sidney for the purpose of inspecting the Dominion Iron and Steel Co.'s plant.

A. L. W.

MINING FIELD WORK.

Last summer, 34 students were engaged in mining field work. The first week was devoted to mine surveying by the entire class in one body. This work was done, as for two years previously, at one of the collieries of the Lehigh Valley Coal Company, Hazleton, Pa., and with the aid of a corps of instructors and assistants, was carried on in three shifts per 24 hours.

After completing the surveying, the students, in squads of two or four, began the usual field work in mining, consisting of at least six weeks of note-taking and sketching. In accordance with arrangements previously made, the squads were divided among some nineteen different mines, as follows:

Copper Range Consolidated Co., Painesdale, Mich.— W. V. Fox, P. Goldman, G. W. Steffen and S. H. Zimmer.

Yak Tunnel, Mining and Milling Co., Leadville, Colo.— C. F. MacCarthy, Jr., G. S. Patterson, J. W. Pulleyn and E. I. Williams.

Humboldt Mine, Morenci, Ariz.— J. B. Kurz and C. J. Mampel.

St. Lawrence Pyrites Co., Stellaville, N. Y.— R. P. Grieve, Y. C. Kuang, J. T. E. Sen and M. Salsbury.

Montreal Mine, Hurley, Wis.— H. E. Bird and C. W. Eichrodt.

Newport Mine, Ironwood, Mich.— T. H. Barrett and C. M. Brister, Jr.

Pennsylvania Gas Coal Co., Irwin, Pa.— J. Cornelissen and J. S. Miller.

Marianna Mine, of Pittsburg-Buffalo Coal Co., Marianna, Pa.—G. W. Schurman and R. C. O'Donnell.

Detroit Copper Co., Morenci, Ariz.— W. R. Grunow and O. A. Fredsall.

Kingston Coal Co., Kingston, Pa.— J. C. Work and S. Federman.

El Tato Mine, Rosario, Sinaloa, Mexico.— I. W. Hadsell.

Mount Hope Iron Mine, Wharton, N. J.— C. Richter.

Bituminous mines at Holden, W. Va.— S. Navarane.

Creighton Mine, Ontario, Canada.— M. Yablick.

No. 5 Slope, Lehigh Valley Coal Co., Hazleton, Pa.— W. F. Pyne.

Besides these, C. E. Meissner for about ten weeks held a position on the staff of the Fayal iron mine, Eveleth, Minn. Kurz, Mampel, Yablick, Navarane, and Federman also worked during part of the summer. R. W. Bissell, N. L. Calder, D. G. Campbell, D. M. Collingwood, and

L. A. Mylius received credit for work previously done in the field. The work of two members of the class was incomplete. A number of the students exceeded the required time, some of them staying in the field nine and ten weeks; on the other hand, several men, though having exceptionally valuable opportunities for observation and study, fulfilled only the bare requirements, devoting a disproportionate amount of time to travelling.

The present class is the ninth to be divided into small squads and assigned to a number of different mines for this course of study. The results are satisfactory. Nearly all of the students did excellent work, both in note taking and sketching, and much valuable engineering material was collected. The note books of Messrs. Brister and Eichrodt are to be especially commended.

The thanks of the School of Mines and of all the students concerned are due to the managers and other officers of the mines visited, for the privileges and assistance so generously given. An expression of special appreciation is due to Messrs. F. W. Denton, Manager, Copper Range Consolidated Co.; A. T. Thomson, Manager, Detroit Copper Mining Co.; David G. Jones, Manager, Pittsburg-Buffalo Coal Co.; F. T. Rubidge, O. F. Pattberg, and K. C. Browne, of the St. Lawrence Pyrites Co.; George H. Abeel, Manager, Montreal mine; L. C. Brewer, Manager, Newport mine; also to the officers of the Lehigh Valley Coal Co., Arizona Copper Co., Yak Tunnel, Mining & Milling Co., Pennsylvania Gas Coal Co., and the Kingston Coal Co.

R. P.

ANNUAL REPORTS.

(Extracts from the Reports of Heads of Departments, for the Academic Year 1912–13.)

CHEMISTRY.

The Teaching Staff.— The active staff during the year 1912–13 included five professors, four assistant professors, 13 instructors, one assistant, and 12 laboratory assistants. For the year 1913–14, the force will be increased by the appointment of an assistant professor in place of an instructor in engineering chemistry; of an instructor in sanitary chemistry; and of two assistants to care for the excess of work involved in giving course 61 for the last time, as well as the new course 67–68 (both qualitative analysis) for the first time, a juncture which will not recur. Three instructors (Drs. Otto Kress and W. C. Moore, and Mr. Logo) resigned at the end of the year, and Dr. Arthur Edgar went on leave of absence for a year. One assistant professor (Dr. Zanetti), two regular instructors, and one temporary instructor (Messrs. W. W. McKirahan, James Kendall and R. P. Calvert) have been appointed. The instructorship in sanitary chemistry is not yet filled.

Overtime Work in Laboratories.— Until this year, while laboratory work was supposed to be done from 1 to 4 p. m., in point of fact, students came up at any time after 1 o'clock, knowing that they could work until 6 p. m. They absented themselves for days in succession, knowing that they could crowd the work in later. The part of the regularly scheduled time which they omitted was largely wasted, and the late laboratory hours took up the time required for study. To the grief of the librarian, the departmental library was little used. On the other hand, the instructors had their time broken up and their strength dissipated by day-long questions and interruptions.

To meet these difficulties, regular laboratory work was confined to the hours of 1 to 4, or other regularly scheduled hours. Thirty minutes' leeway was allowed for finishing experiments. All students were required to report for work promptly, and to cease work at the end of the period. Since it was not the purpose of these regulations to hamper laboratory work, but to further it, individuals finding themselves in the midst of an experiment at closing time received from the instructor a permit card for a definite period of overtime work good for that day only. During the year only 46 of such permits were requested.

Students whose circumstances made it necessary for them to work temporarily or permanently at over-time hours (generally 9 to 12 and 4 to 6, or in the evenings, or on holidays) received a regular overtime permit. This was granted by the head of the department upon recommendation of the instructor concerned. Only 11 such permits were issued, this being the whole number recommended.

The result showed that only a very few overtime permits were asked for, and therefore little time was needed for the administration of the plan. The advancement of the classes with their work was more rapid than in former years. The librarian complained that there were not lights enough in the departmental library for those desiring to study

there, and more were installed. The instructors gave better instruction. During the assigned hours they devoted themselves exclusively to teaching, and concentrated their attention upon this, knowing that during the rest of the day they would be free from interruptions and able to settle down to research or preparation for class-work.

Independent Workers.— Frequent requests come from residents of the city, and others, for permission to make analyses and experimental studies of industrial problems in the laboratories. As a rule, their evident desire is to use the facilities and materials in the laboratory, and to benefit by consulting with the instructors, in the expectation of getting results of considerable commercial value at little or no cost to themselves. There is little difference between their case and that of an expert who should desire to conduct the work for his clients in our laboratory instead of renting one for himself. We have no room to accommodate such workers, even if it were advisable to do so. Finally, one of the purposes of the Chemists' Club Building Co. was to provide private laboratories and to rent them to transient as well as to more permanent tenants. For these and other reasons, the subjoined *Regulations for Independent Work* were devised, and have been approved by the President and Treasurer. These regulations do not affect the custom of the laboratory, in accordance with which officers of municipal and other public bodies, and of educational and research institutions, have received facilities for carrying on work of value to the public or to scientific research.

1. The worker registers as a non-matriculated student in Applied Science.
2. The worker pays $75 per half-year.
3. In addition, the worker deposits $100 to guarantee the return of all apparatus and materials borrowed, and payment for supplies, breakage, and service. The unused balance will be refunded.
4. In case of the work's ceasing before the expiration of the half-year, the University will refund $7.50 of the $75 for each whole month by which the period falls short of a half-year.
5. The laboratory shall not be open for this work excepting within the hours at which it is regularly open to students.

Divorce of Graduate from Undergraduate Work.— Prior to the establishment of three new graduate courses, there was only one course (aside from research) offered in the department, which was not required of the chemists or chemical engineers, and mainly devised for undergraduates. The undergraduates carry so many courses simultaneously that the exaction of reasonable preparation and independent thought, habits to which they seem to be unaccustomed, is found to be impossible. Hence the graduates discourage the undergraduates by setting too swift a pace and going into the subject with (relatively) bewildering thoroughness. A divorce of the two groups was the only remedy, and it has been amply justified.

Nichols Laboratories.— The new Nichols laboratories of inorganic chemistry, occupying the sixth floor of Havemeyer Hall, were ready for use at the beginning of the year. Without them, the largely increased number of students could not possibly have been accommodated in the building. The two large laboratories contain respectively 128 and 92

working places, and lockers are provided for four sections working at different times, or a total of 890 students. The smaller laboratories afford more ample space for 50 to 80 instructors, assistants, and advanced students, making a grand total for this floor of 940–970 workers. The plans included lockers for 128 additional students, which lockers can be added at any time without disturbing the present desks or plumbing. The other floors were not planned with a view to accommodating large numbers of workers, and the total capacity of all the other five floors, as at present equipped, is not over 350, or about one-third of the capacity of the sixth floor alone.

Engineering Chemistry.— This sub-department has been busily engaged during the past year in the installation of laboratory equipment, such as pumps, filter-presses, centrifugals, distilling apparatus, etc., a brief description of which may be found in the *Journal of Industrial and Engineering Chemistry,* Vol. 5, page 304.

The long-established close relations of this department with industrial chemistry, the recent establishment of a chair in engineering chemistry, the appointment of Professor Whitaker to this chair, and the beginning that has been made in the creation of a suitably equipped laboratory, have all attracted much attention, and aroused high expectations. A single piece of evidence, out of many that might be given, may be noted in support of this statement. Of the many prospective students who write for information, about one-third mention the particular branch of chemistry in which they desire to specialize. Of the letters of the latter kind, received during the twelve months ending November 1, 1912, 1 mentioned organic, 1 agricultural, 5 food, and 38 engineering chemistry. The numerous letters received since that date show a similar preponderance of these interested in this line of work.

Against this must be set the fact that the department lacks equipment and instructors for several important courses given in other laboratories of industrial chemistry. It could not provide means for research (for Ph.D. dissertations) for even one-tenth of these 38 applicants, if they should ultimately decide to come.

The transfer of Assistant-Professor Metzger to this sub-department, in place of Dr. Kress, resigned, is a distinct evidence of the intention of the University to strengthen this work. Dr. Metzger has an unusually minute and extensive knowledge of matters pertaining to industrial chemistry, and much experience in investigations along this line. He is therefore especially well fitted, not only to carry on the courses formerly given by Dr. Kress, but also to bear his share in directing the work of research students.

CIVIL ENGINEERING.

The work of this department for the year 1912–13 exhibited at least two features of marked character which distinguish it from that of any previous year. The first was that the graduating class, numbering 36, was by far the largest class that has ever received the degree of Civil Engineer in any year since the course was established. At the same time this class was considerably larger than that graduating in any

other department of the School of Mines, which also occurred for the first time in the history of this Department. The second feature was that research work was begun under the favorable conditions afforded by the income from the William R. Peters Fund, and will hereafter be carried on continuously, up to the limit permitted by the available income. It is further a matter of gratification to record a highly successful year in the graduate work in highway engineering; the number of students has materially increased and the work has gained in interest and vigor.

While in former years the course in sanitary engineering has been in nominal existence, with usually one or two students working under unsatisfactory conditions on some special subjects in this field, it has scarcely been proper to call what the Department had to offer an effective course in sanitary engineering. Under the management of Mr. D. D. Jackson this situation has most fortunately been fundamentally changed. Although the facilities which have been at the disposal of Mr. Jackson were meagre in most respects, he has accomplished results of high excellence and for the first time in the history of the school a true and effective course in sanitary engineering has been given to those students in civil engineering who have desired to follow that specialty. Arrangements have been made by which the facilities of the past year are to be much extended, and the opportunities for work in those technical subjects on which sanitary engineering is chiefly based will be greatly broadened and improved. It may now be confidently stated that the course in sanitary engineering at Columbia University will hereafter be at least abreast of the courses given in other prominent engineering schools of the country.

The staff conducting the work of the Department of Civil Engineering consists at the present time of three professors, two assistant professors, three instructors, two assistants and one lecturer, a total of eleven. At the beginning of the year 1913–14, Mr. Jackson will become Assistant Professor, and the position of lecturer will cease to exist. In a previous report to the President, I have shown that the average number of students per instructor, per class room exercise, during the past year, with the exception of the initial work in sanitary engineering, has been forty, showing that the number of instructors of all grades is too small to reach with the degree of efficiency that ought to characterize the best technical instruction the number of students which may be effectively served by a single instructor.

The number of students attending the graduate course in highway engineering, extending from Dec. 1, 1912, to April 1, 1913, was 41. They were registered from the following fields of practice: ten from State highway departments, two from county highway departments, nine from municipal highway departments, one from university work, two from contractors' organizations, 12 from engineering research and chemical departments of companies manufacturing bituminous materials, two from the engineering departments of companies manufacturing road machinery, and three from miscellaneous fields. Four of these graduate students received the degree of Master of Arts. In addition to the

regular lecture work of the course, some of which were given during evenings, there were 21 "University Lectures" on highway engineering, given by eminent non-resident practitioners from different parts of the country, on a wide range of subjects directly related to the graduate course of study.

The development of this work under Professor Blanchard has certainly yielded encouraging results up to the present time and I shall be greatly surprised and disappointed if the development does not continue to be equally gratifying. The quality of the work done by the students in this course is unusually excellent. They are nearly all young men engaged in active professional work and intensely interested in the advanced instruction which they receive.

ELECTRICAL ENGINEERING.

The most interesting item of news concerning the work of this department is the fact that of the 18 naval officers detailed to Columbia University for post-graduate work in engineering, nine are registered in electrical engineering and two in radio engineering. These men are taking post-graduate work, the electrical engineers devoting most of their time to courses in electrical engineering and a portion to courses in mechanical engineering, while the radio engineers divide their time between Prof. Pupin's research laboratory and courses in the Department of Electrical Engineering.

Changes in Staff.— The only changes in the staff are the resignation of two assistants, Messrs. Graetz and Stavely, to accept positions with the Crocker-Wheeler Company, and the appointment of Mr. B. P. Hamilton, E. E., Columbia, 1913, A. S. Hill, E. E., Polytechnic Institute, 1911, E. H. Armstrong, E. E., Columbia, 1913, to be assistants for the year 1913–1914.

New Equipment.— The following apparatus has been added to the laboratory equipment of the department:

One 7½-kw. flywheel motor generator set, consisting of a direct-current motor driving a 3-phase or single-phase alternating-current generator for any frequency from 25 to 80 cycles. This is intended to facilitate the standardization work by providing a source of absolutely constant potential and frequency.

One 5-kw. synchronous converter.

One 4-kw. compound-wound generator.

One Siemens-Halske Epstein iron testing outfit.

Seventeen new instruments, including a 3-wire watt-hour meter and a new 0.01-ohm standard shunt for calibration work.

Several new 3-phase adjustable reactance coils have been built in the laboratory by the department.

Our laboratories have been still further simplified by the removal of various pieces of apparatus which, although useful, have not been of sufficient utility to warrant their occupying valuable floor space. On account of the large number of men working in the laboratories at one time it has been found necessary to remove every piece of apparatus

that is not absolutely essential to the work, in order to provide space. In line with this policy, the museum of the department has been practically abolished in spite of its value, to make room for the new engineering library which is considered to be of greater value.

Work for the City of New York.— During the past year, under the contract with the Department of Water Supply, Gas and Electricity, 48 meters and 236 devices have been tested. Among the devices were 15 different types of arc lamps which were given a life test to determine their suitability for purchase by the City. Each lamp was operated from 200 to 600 hours, or practically to destruction. The work for the City has grown so much in extent that it has been estimated that if the department charged for the work at the same rate at which commercial laboratories make their charges, the bill would have amounted to over $4,000. The University received $1500 for this work. Steps are being taken to have this matter readjusted on a more equitable basis.

Electrical Engineering Society.— This society held a number of meetings in the past year, but not so many as in the preceding years, since the meetings had not been very well attended. A new policy was adopted last year of holding fewer meetings and making more a feature of them. This seems to be strengthening the interest in the society. The officers elected for the ensuing year are: President, S. Fisher, 1914, Vice-President, S. Jaques, 1915, Secretary, H. Elsasser, 1914, and Treasurer, H. C. Nolte, 1914.

Literary Activities.— During the past year Prof. Morecroft has published his book, "A Laboratory Manual of Alternating Currents," which serves as a text-book for the fourth-year students in electrical engineering. Thus, three out of the five laboratory courses given by the department are fully covered by text-books already published, while Mr. Hehre has material for a book covering the fourth course in preparation for publication.

During the past summer Prof. Arendt has completely revised and largely re-written his book on "Electric Motors" and has invented and developed an electric generator for railway train and automobile lighting.

Prof. Slichter has completed the chapters on "Design of Electrical Machinery" for a new handbook which will appear in the Fall, and will be used as a reference book for all courses on design in the department. Prof. Slichter lectured before the post-graduate engineers of the Navy at Annapolis on the "Application of Electric Propulsion to Naval Vessels."

The newly elected President of the American Institute of Electrical Engineers, Mr. C. O. Mailloux, formerly associated with Columbia, has made the following appointments to the committees of the A. I. E. E. from the staff of this department:

Prof. Slichter, Chairman, Committee on Technical Lectures and a member of the Editing and Library Committees.

Prof. Arendt, member of the Standards Committee and of the sub-committee on Safety Devices.

Prof. Morecroft, member of Committee on Education.

Disposition of Graduates.— Of the graduating class, four men were offered positions on the General Electric student course and two accepted; three men were offered positions on the Westinghouse student course and one accepted. Most of the men are placed, the exceptional men having had two or three opportunities, while each man has had a definite offer and there remain a number of opportunities unfilled. Several of the third-year electrical engineers obtained positions for the Summer with the large companies; thus one who is interested in signal work was taken on the student course in the Union Switch & Signal Co., another with the Westinghouse Co., and a third on the construction force of the General Electric Co. in New York City.

GEOLOGY.

The past year has been marked by one very important new departure in this department. Instruction on the physiographic side of the subject was begun last September by Associate Professor Johnson, and will be made an increasingly important part of our work. Dr. Johnson has given an elementary and an advanced course in his special field and has shared to some extent in the general instruction in geology. By well-timed efforts he has secured important additions to our equipment in physiography and will give his courses in 1913–1914 with improved facilities over 1912–19'3. Many hundreds of photographs have been secured and mounted and notable additions have been made to the teaching equipment in maps and lantern slides. A special room was fitted up during the Summer for the maps, which will be a definite part of the reorganized departmental library. The Great Northern Railway and the Denver & Rio Grande system have been very generous in aiding us with photographs and lantern slides.

Dr. Johnson also undertook several months ago the establishment of a fund whose income should be devoted to the acquisition of lantern slides, and photographs, which should be named the William O. Crosby Fund, in honor of Professor Crosby, long the teacher of geology in the Institute of Technology, in Boston, and a close and valued friend of all the officers in our own department. The sum of $1800 was subscribed for this purpose and was accepted by the Trustees. The fund is the first special endowment of any feature of the department's work, aside from teaching, and is of a kind which is extremely serviceable. While not requiring excessive amounts, the plan at the same time affords a valued memorial. An income of $80 to $100 per annum means 200 to 300 lantern slides and improved facilities in this important adjunct to instruction.

Our departmental library has hitherto been shelved in one small room and in several professors' offices on three different floors. It will now be assembled at the northern end of the museum of economic geology, where very commodious and attractive quarters can be supplied for shelves and tables. In the adjoining room, the maps will be brought together. The departmental set will be augmented by the important series donated to the University by the Germanistic Society, when the distinguished geographer Dr. Albrecht Penck was the Kaiser Wilhelm

professor. The latter collection covers the German and Austrian empires, and is of great service in instruction. While we realize that the American Geographical Society is near us and is well provided with a very complete reference collection of maps, we need a working series for instruction, which we will make more and more efficient as time passes. We are realizing the plans formulated fully 20 years ago for the organization of the department, and we find ourselves now with provision for the most important divisions of the large subject of geology.

Professor Grabau was the administrative head of the department during my half year of sabbatical leave last Fall, and very kindly assisted in the partition of my instruction, so that the leave of absence was cared for without adding even temporarily to the staff. The accession of Dr. Johnson made the temporary arrangement practicable. To Professor Grabau, my acknowledgments are due and are gratefully rendered. The work on the stratigraphical and palæontological side has successfully progressed.

We maintained during the year the custom earlier inaugurated of having as Curator in palæontology a representative from one of the German universities. This year Dr. Clemens Lebling, from the University of Munich, has been with us and has very faithfully and efficiently performed his duties. He has added a distinct element of strength to the department. Professor Grabau's assistant, Mr. Hintze, received his Ph.D. at Commencement. Coming to us after several years of graduate work elsewhere, he has for the past two years done excellent work with us.

The past Fall, Professor Berkey met the desire of a large number of fourth year mining engineers for additional instruction in petrography, by a one term special course instead of offering them only the first half of the full year's course. The work has proved satisfactory and welcome. It has been given largely in the way of problems dealing with questions which have come up in mining and other engineering operations, which can be helped toward solution by the use of the microscope. Nearly 100 such cases have now been submitted either to Dr. Berkey or to me and we have saved the instances and the preparations used in their solution as clinical material for our mining students, in the last year of their course. We have found the use of the microscope so serviceable in these connections that for our graduate students also, many of whom are interested in the problems of the ores, we have planned special work in the second term. Dr. Berkey will give hereafter a short course dealing with these matters and for his equipment with thin sections and other materials we have found funds without drawing in any way on the University appropriations. Dr. Berkey bore the chief burden of instruction imposed by my sabbatical leave the first semester and to him by acknowledgments are especially due. Dr. Berkey has continued in active service to the City as consulting geologist to the Board of Water Supply and has been an important aid in the engineering problems raised by the deep tunnel aqueduct beneath the City.

Two candidates for the Ph.D. in geology received their degrees at

Commencement, and one other needs only the printing of his dissertation to fulfil the requirements. A larger number of candidates for the master's degree also received their awards. From 25 to 30 graduate students have been working with us, and we have all felt that the instruction, both undergraduate and graduate, has been going on with life and interest.

MECHANICAL ENGINEERING.

The Instruction.—No important changes in the subject matter of the courses have occurred during the past year. The use of Professor Lucke's text in the course in thermodynamics has enabled us to use the recitation system with much success. Text-books for all courses are being prepared as rapidly as possible, with a view to having all courses conducted on the recitation plan. During the past year the graduate school of the Naval Academy at Annapolis has made an investigation of the most important engineering schools in this country with a view to detailing Junior officers to residence at such institutions where the instruction is found to be of superior order. It is most pleasing to note that the result of their investigation has led to their decision to have their Junior officers come to Columbia. The work of this department was most pleasing to the officer in charge of the graduate school and favorable comment was made on the courses in machine design. This department laid out the courses of instruction followed by the officers at the Brooklyn Navy Yard in the Summer of 1913 and has been asked to coöperate in the supervision of this work.

The amount of instruction measurable by student-hours which has been given by the department during 1912–13 was in excess of the amount given during the previous year; of the total student-hours instruction given, 53½ percent. was given to students from other departments. During the previous year the percentage of student-hours commanded by other departments was also 53½ percent., while in 1910–11 it was 46½ percent. The great demand in the department has not permitted the accomplishment of graduate instruction, a fact which is very discouraging, especially at the present time when we are planning for a graduate school. It is hoped that facilities and time will soon be afforded to this department to accomplish those things for which it stands.

Our Needs.— So many conferences have been held and such a quantity of reports exist on this most important topic that I can but repeat what is already so well recorded. We are now outgrown beyond our laboratory and drafting room facilities and we are most seriously handicapped. Almost all of our sister universities possess, or are providing, new shops, new laboratories and new drafting rooms. Cornell, Purdue, Mass. Inst. of Technology, Illinois, Yale, and even the smaller schools are putting up new engineering buildings on much less provocation than exists here. We are advertising new graduate courses, and are placing ourselves before the world as being prepared to give instruction which is of an order not elsewhere obtainable, yet no improvement has taken place in the provision of equipment. We are crowded in small offices, some men having space which is worse than that provided for many clerks and stenographers about the University. Every member of the department

is alive to the unusual advantages we possess in the way of location, the need for mechanical engineering instruction and research of a high order, and it is hoped that adequate staff increase and material equipment will soon be provided.

METALLURGY.

The only change made in the organization of this department was the appointment of Mr. Harold P. Banks, as assistant. This addition has enabled the staff to handle the work in a very satisfactory manner and with very much more ease than heretofore. No material changes have been made in the courses of instruction given. In one or two cases the method of instruction has been modified and the informal conferences on metallurgical subjects which we instituted the previous year have continued with very satisfactory results.

A total of 26 courses were offered and students registered in all of them. The total number of students registered in one or more of these courses was 291 as follows: Special students, 5; School of Chemistry, 52; School of Engineering, 118; School of Mines, 97; College, 10; candidates for advanced degrees, 9. This is an increase of 13 over the preceding year.

Instruction has been carried on very successfully during the past year, and the regular lecture courses have been arranged so as to be up to date. A number of bromides have been added for illustrating lectures and new lecture notes have been most carefully prepared in some of the courses. Nine students were registered in metallurgy for advanced degrees and have taken major or minor subjects in this department. Their work has been satisfactory in every respect. The amount of research work was less than usual, although several interesting subjects have been handled in this connection.

The summer field work in metallurgy during 1913 consisted of visits to the various plants around New York, a careful inspection of the iron and steel works in the vicinity of Pittsburgh, and a trip with the metallurgical students to Chicago, Omaha, Denver, Colorado City, Pueblo and Salt Lake. The trip was eminently satisfactory and the men taking it were benefited greatly by what they saw.

The new assay laboratory, which was installed last year on the sixth floor of the School of Mines building, has given complete satisfaction and is considered one of the best assay laboratories in the country. The students have been able to accomplish very much more work than in the past, and the results are better in every respect.

Practically no changes have been made in the ferrous and non-ferrous laboratories, and the additions which have been made were of a minor character.

A number of specimens were added to the collection in the museum, and next year we expect, with the assistance of some of the former graduates of the School of Mines, to make further additions in order to bring the collection up to date.

MINERALOGY.

A new course was given to the chemists of the third class in the second half-year, which was designed to supplement the short course in mineralogy hitherto given. A further drill in sight recognition was given with an increase in the number of species so studied from 70 to 120. Considerable time was devoted to crystallography, in recognition of its steadily growing importance to the chemist, and each student was given practice in measurement, projection, graphic determination of indices and calculations of constants.

The microscopic study of minerals, including the fundamental optical characters, and particularly the application of these to the determination of minerals in crushed fragments, also received attention.

A feature of the year was the increase in quantity and variety of material for study, made possible by the grant of an additional helper who, having nothing directly to do with the teaching, devoted his time to the arrangement and preparation of material. It is desirable and almost necessary to have in the working collection material from all important localities for all important minerals. A good start has been made and new material was obtained in quantity from fifty or more localities in this country and Canada, Mexico, etc., and some hundreds of letters are in preparation to graduates and friends of the University in other localities to secure more.

During the summer Prof. Moses gave a course on gems and gem minerals. In planning the course the editor of the *Jewelers' Circular* and prominent experts like Dr. George F. Kunz, Mr. Meyer D. Rothschild, and the heads of various cutting and polishing houses have been consulted.

The few cut specimens already in the museum were supplemented by gifts from Tiffany & Co., the American Gem and Pearl Co., Julius Wodiska, the Tecla Co., the Remoh Co., and others, and a number of specimens from the general collection were cut and polished so that cut and uncut representatives of nearly all the important gems and ornamental stones, and also of imitation and synthetic gems, were available for study.

Amongst the publications of the department have been: "Guide to the Sight Recognition of 120 Common and Important Minerals" and a "Scheme for Utilizing the Polarizing Microscope in the Determination of Minerals" by Professor Moses. Dr. Luquer's "Minerals and Rock Sections" has been revised, and a fourth edition has been published. Mr. Bruce, the assistant in mineralogy, has undertaken a careful study of the opaque minerals by what is called the methods of metallography, that is, by polishing, etching, microchemical tests, etc., and has already examined about 50 varieties and tabulated the results. It is expected that these will be supplemented by further studies next year and will form the basis for a scheme for the determination of opaque minerals.

The large collection of pamphlets which have accumulated in the department for the past twenty years, which has hitherto been filed by authors, has been rearranged in a manner which will make it available either by authors or by subjects with very little trouble.

MINING.

During the past academic year there have been no changes in the staff of the department, and the several courses of instruction have been given as scheduled. The summer class in mine surveying was held at Hazelton, Pa., in June, 1912, and again at the same mine in 1913, under the direction of Professor Kurtz and Mr. Judd. The summer work in mining last summer and this follows the plan of recent years and the students are scattered at numerous mines in small sections for the required work.

During the past year Mr. R. V. Norris, of the class of 1885, delivered a course of 20 lectures on anthracite mine practice, covering the subjects of shaft sinking, ventilation, power plant, coal storage and handling, preparation of anthracite, mine accidents, etc. Mr. J. R. Finlay gave six lectures on mine valuation, and mining costs. Mr. H. L. Mead, of the class of 1890, gave a lecture on hydraulic mining. The above lectures were arranged to form integral parts of the regular lecture courses, and replaced and supplemented the work of the regular staff.

FACULTY NOTES.

Dr. J. E. Zanetti who resigned from the department of chemistry a year ago to become Director of the Institute of Industrial Chemistry of Uruguay, at Montevideo, has returned to Columbia as Assistant Professor, in charge of the courses in qualitative analysis.

Professor C. E. Lucke gave the first public exposition of his latest researches in the design of surface combustion appliances before the eighth annual meeting of the American Gas Institute, in October, 1913. The account was published in full in the *Proceedings* of the Institute.

The degree of LL.D. was conferred on Prof. M. C. Whitaker, head of the division of engineering chemistry, by the University of Colorado, in June, 1913.

James F. Kemp, Professor of Geology, was given the degree of LL.D. by McGill University, on Aug. 2, 1913.

Prof. S. A. Tucker was recently elected vice-president of the American Electrochemical Society.

Dr. W. C. Moore resigned his position as Instructor in the department of chemistry, early in 1913, to become research chemist for the National Carbon Co., of Cleveland, Ohio.

Emeritus Professor F. R. Hutton has accepted the position of general secretary to the National Highways Association, an organization devoted to the encouragement of good highways throughout the country.

The Royal Society of Edinburgh, on July 25, 1913, awarded its Keith medal to Prof. A. Smith in recognition of his researches on sulphur and vapor pressures. Prof. Smith has recently served as chairman of a commission appointed by the College Entrance Examination Board to revise the entrance requirements in chemistry. The second revised and enlarged edition of Prof. Smith's "Einführung in die allgemeine und anorganische Chemie" appeared in November, 1912.

Arthur H. Blanchard, Professor of Highway Engineering, attended the Third International Road Congress, in London, in June, 1913, having been appointed a delegate by Columbia University, the A. S. C. E., the National Highways Association, and the American Road Builders' Association. He was accompanied by Henry W. Durham, C. E., '95; Francis P. Smith, Ph.B., '88; and Edward T. Thomas, of '95. At the close of the Congress, Prof. Blanchard studied pavements in England, France and Germany. On his return, he was appointed a member of the United States committee on "Standardization of Nomenclature of Road Materials," working in coöperation with the Engineering Standards Committee of Great Britain. More recently, he has been retained as consulting engineer to the Department of Efficiency and Economy of the State of New York, and also to the State Highway Department of Pennsylvania.

Prof. M. T. Bogert spent the early months of 1913 in travel through Europe, where he was the guest of the leading chemical societies. As retiring president of the Society of Chemical Industry, he delivered an address at the annual meeting of the society at Liverpool, in July.

Dr. H. L. Fisher, Instructor in Chemistry, was elected national secretary of the honorary chemical society, Phi Lambda Upsilon, in November, 1912, and in March, 1913, attended a biennial convention of the society in Milwaukee.

Harold Perrine, of the department of civil engineering, has been conducting extensive tests on cinder concrete, in connection with the New York City Bureau of Buildings. Some of the results were published in *Engineering News,* Oct. 9, 1913.

Prof. H. C. Sherman, of the department of chemistry, was designated a research associate for 1913 by the Carnegie Institute, Washington, D. C. He is also a member of the committee on hygiene of the American Museum of Safety and Sanitation.

ALUMNI NOTES.

1885. Richard Moldenke, E. M., Ph.D., Watchung, N. J., was recently elected vice-president of the American Society for Testing Materials. He also holds the office of vice-president of the board of managers of the New Jersey State Village, to which he has been appointed and reappointed by four governors.

1887. George F. D. Trask, E. M., is president and treasurer of S. F. Hayward & Co., fire protection supplies, 39 Park Place, New York.

1887. F. M. Simonds, E. M., of Simonds & Burns, New York, spent the autumn of 1913 in Cuba, on professional work.

1887. George S. Rice, chief engineer with the U. S. Bureau of Mines, has invented a new form of mine cage for use in mine rescue work. One of them was used successfully at the Banner disaster, and more of them will become part of the equipment of the mine rescue cars.

1892. Heinrich Ries, Ph.D., Professor of Economic Geology at Cornell University, attended the international geological congress at Toronto, as delegate from Cornell. He spent the remainder of the Summer in finishing an investigation of the clay deposits of British Columbia, for the Canadian Geological Survey.

1893. Luther E. Gregory, C. E., Lieutenant Commander in the U. S. navy, has been transferred from Portsmouth, N. H., to the Puget Sound navy yard at Bremerton, Wash.

1894. H. K. Masters, E. M., is now with the Griffin Wheel Co., at 445 No. Sacramento Boulevard, Chicago, Ill.

1895. H. W. Durham, C. E., has returned from a protracted trip throughout Europe, which he spent in investigating the construction of roads. Previously, he attended the International Road Congress, in London, to which he was appointed delegate to represent the City of New York.

1895. C. S. Herzig, E. M., has been made Chairman of the Mid-Continent (Oklahoma) Oil Co.

1895. B. B. Gottsberger, C. E., general manager of the Miami Copper Co., recovered from his serious illness in Los Angeles, and has resumed his duties at Miami, Ariz.

1897. George W. Magalhaes, E. E., was recently appointed general inspector for the Toronto Electric Light Co., with which concern he had previously been connected for a year.

1900. Benjamin Magnus, E. M., is now general manager of the Mount Morgan Gold Mining Co., at Mt. Morgan, Queensland. He has been successful in his search for an available coal deposit in central Queensland, and expects to obtain from it shortly most of the fuel and coke required by the gold mining company.

1900. J. R. Wemlinger, President of the Wemlinger Steel Piling Co. and Secretary of the American Society of Engineering Contractors, was

chairman of the contractor's session at the Third American Road Congress, held in Detroit, Mich., Sept. 28 to Oct. 4, 1913.

1901. Carl G. A. Schmidt, Mech. E., is associated with the H. W. Pickett Co., Harrison Bldg., Philadelphia, dealers in general contractors' equipment.

1901. Morrison B. Yung, E. M., has opened an office for mining and assaying work at 2 Gresson St., Wanchai, Honkong, China.

1902. Joseph A. Close, C. E., is in charge of the engineer corps of the Balboa terminals of the Panama canal. Address: Balboa, Canal Zone.

1902. Frederick B. Irvine, C. E., was recently elected associate member of the A. S. C. E. He is division engineer in charge of construction of a 202-kilometer railroad for the National Railroad of Haiti, of which 159 kilometers are already in operation. Address, Caribbean Construction Co., 55 Wall St., New York.

1902. Frederick H. Morley, E. M., has left Denver, and has opened an office at 1321 Wood Ave., Colorado Springs, Colo.

903. W. M. Wishman, E. M., superintendent of the Bingham-New Haven mine, Bingham, Utah, visited New York with Mrs. Wishman, in October, 1913.

1903. C. G. Gunther, who for some time has been in charge of a copper mine on the island of Cyprus, returned to New York in October, 1913, to take up the study of archeology, having become deeply interested in such matters from his residence on classical soil.

1903. H. C. Wilmot has resigned as superintendent for the Colorado Mining Co., Aroroy, Masbate, Phillipine Islands, and has become manager of the Syndicate, a neighboring property, which is building a 100-ton cyanide mill.

1904. Milton H. Fies, E. M., has been appointed vice-president of the Maryland Coal and Coke Co., of Birmingham, Ala. Address, Jasper, Ala.

1904. William P. Abendroth, E. E., was married, June 5, 1913, to Mabel Maria Willets, at Harrison, N. Y.

1905. H. N. Lawrie, E. M., was elected chairman of a commission appointed by the Governor of Oregon, under legislative enactment of 1913, creating a Bureau of Mines and Geology, with offices at 526 Yeon Bldg., Portland, Ore. The chiefs of the field parties include several of the best known geologists of the northwest, and results of their investigations will be available early in 1914. Mr. Lawrie will continue his professional practice. He visited New York in September.

1905. Robert B. Rogers, E. M., recently with the New York and Honduras Rosario company of Honduras, is now secretary-treasurer of the Davis-Rogers Company (Inc.), engineers and contractors, with offices at 621 Monadnock Bldg., San Francisco, Cal.

1905. M. Gardner Talcott, E. M., has resigned his position as manager of the Dome Lake Mining and Smelting Co., Porcupine, Ontario.

1905. Lewis F. Pilcher, Ph.B., was appointed State Architect of New York, by Governor Sulzer.

1906. Robert McL. Johnson, E. M., until recently superintendent of the Adventure Cons. Copper Co., Greenland, Mich., owing to the cessation of work due to the strike in the copper country, has returned to New York and is spending a few months in advanced study of geology and ore dressing at the University.

1907. B. F. Tillson, E. M., was married, July 9, 1913, to Florence R. Smith, at Newton, N. J.

1907. George E. Farish, E. M., has left Sheep Creek, B. C., and is now at 25 Broad St., New York City.

1907. Thomas H. Tulloch, E. M., has been appointed superintendent of the concentrator of the South Utah Mines and Smelters, Newhouse, Utah. He is a member of the Utah Alumni Association of Columbia University.

1907. M. F. Sayre, E. M., recently located at the Croton Magnetite Iron mines, Brewster, N. Y., was in New York in October.

The Braden mines, at Rancagua, Chile, seem to be in good hands. Robert Marsh, 1907, is mine superintendent; O. M. Lewyn, 1908, is assistant mine superintendent; H. R. Graham, 1908, is mine foreman; John D. Tallant, 1910, is assistant mine foreman; Lester E. Grant, 1909, is assistant mill superintendent. In June, 1913, the Columbia representation was augmented by G. L. Helmrich, 1909, and P. E. Locke, 1909.

1908. Robert Annan, E. M., is in the London office of A. Chester Beatty, E. M., '98.

1908. Marco C. Smith, Jr., C. E., is employed in the bridge department of the Louisville & Nashville Railroad. Address: Chesterfield Apartments, Louisville, Ky.

1908. A. W. Newberry, Met. E., formerly with the Mammoth Mt. Mining Co., is now at the Tumco mine, Tumco, via Ogilby, Cal.

1909. L. M. Bernfeld, C. E., has just published a 240-page book entitled "Erection and Inspection of Iron and Steel Constructions."

1909. D. B. Steinman, C. E., Ph.D., has been promoted to the rank of full Professor of Civil Engineering in the University of Idaho, Moscow, Idaho. Articles by him on the subject of bridges have appeared in *Eng. Rec.*, May 17 and 24; *Eng.-Cont.*, May 7; *Pacific Builder and Engineer*, Apr. 12, and May 10, 1913.

1909. Harold O. Knapp, Mech. E., Crockett, Cal., visited New York in December, 1913, to make a special study of sugar refineries.

1910. Victor Ziegler, A. M., has been promoted Professor of Petrography and Mineralogy in the South Dakota State School of Mines. He spent most of the past Summer in a study of the mineral deposits

of the Harney Peak district of the Black Hills, the results of which will shortly be published by the State.

1910. D. L. C. Hover, E. M., lately of Asarco, Durango, is now employed by the Cia. Metalurgica Nacional, at Matehuala, S. L. P., Mexico. It took him three months to make the trip, having been detained in Torreon by revolutionary activities.

1910. D. M. Obler, E. M., who has been at the Tiro General mine, Charcas, S. L. P., Mex., visited New York in October, 1913.

1910. Marion H. Merriss, Met. E., was married, Sept. 17, 1913, to Laura L. Ramsay, at Perth Amboy, N. J. Address: Hotel Belvedere, Baltimore, Md.

1910. Victor H. Carples, E. E., for the past year has been sales manager for the L. J. Wing Manufacturing Co., New York. Address: 505 W. 143d St.

1910. Homer L. Carr spent the month of July in the examination of alluvial gold deposits in the Dominican Republic. In September he went to Colombia to drill the Mapuri tract on the Nechi River, a few miles below Zaragoza, for the Colombia Gold Mines Corporation.

1910. T. B. Counselman, E. M., has left the Inspiration Copper Co., at Miami, and is now at Morenci, Ariz. P. O. box 657.

1911. Robert W. Briggs, C. E., is in the engineering office of the New York Central Railroad at Poughkeepsie.

1911. W. E. Buchtenkirch, C. E., is with H. C. Keith, consulting engineer, 116 Nassau St., New York.

1911. F. S. Frambach, Mech. E., was married, Aug. 30, 1913, to Elminil W. Alpaugh, at Plainfield, N. J.

1911. A. R. Fletcher, E. M., passed through New York in October, 1913, on his way to take charge of a French gold mining concern in Venezuela.

1911. G. A. Jahn, Jr., with the Miami mine, Miami, Ariz., was in New York in October, 1913.

1911. A. A. Leach, E. M., general manager of the Sonora Exploration and Metals Co., San Javier, Sonora, Mex., was married Oct. 19, 1913, to Frances Ivan Foster, at Tucson, Ariz. Address will be San Diego, Cal.

1911. Felix Riesenberg, C. E., 1911, 15 Alsop St., Jamaica, N. Y., who is connected with the Department of Parks, Borough of Queens, reports the birth of a son, Felix, Jr., on Aug. 5, 1913. An article by him, entitled "When Sailors were Sailors," recounting his experiences on a sailing voyage around Cape Horn to Honolulu, appeared in *Outing Magazine* in Aug., Sep. and Oct., 1913.

1911. Charles R. Fettke, A. M., has been appointed Instructor in Geology at the Carnegie Institute of Technology, Pittsburg, Pa. He spent the Summer as assistant to M. A. Pishel in mapping the geology

of the Red Mesa and Soda Cañon quadrangles, in southwest Colorado, for the U. S. Geological Survey.

1911. Sidney L. Wise, E. M., is connected with the Mines Management Company, 60 Broadway, New York, on whose behalf he has been engaged in exploratory work for the Vermont Copper Co. Permanent address, 28 East 63d St., New York.

1911. John M. Lovejoy, E. M., recently with the Chile Copper Co., Chuquicamata, Chile, is now superintendent of the Minas San Juan, Huantajaya (via Iquique), Chile.

191'. Harold B. Jenkins, Mech. E., is engaged with the structural engineering department of the Panama-Pacific International Exposition, at San Francisco. He was recently elected junior member of the A. S. Mech. E. Permanent address, 41 St. Nicholas Terrace, New York.

1911. Percy R. Iseman, E. M., having recently returned from South America, is with the E. A. L. Construction Co., 505 Fifth Ave., New York.

1911. W. R. Wright, having returned from Chile, has formed a partnership under the firm name of Stafford & Wright, to deal in iron and steel and contract for structural work of all kinds, with offices at 114 Liberty St., New York. He was married on Feb. 18, 1913, to Agnes R. Mackenzie, of New York.

1912. Julian Loebenstein, E. E., has been with the General Electric Co., at Lynn, Mass., for the past year. After competitive examination, he has recently been appointed junior railway engineer with the public Service Commission, First District. Permanent address, 67 E. 84th St., New York.

1912. R. Tarantous, E. M., transitman with the Shannon Copper Co., at Metcalf, Ariz., spent a vacation in New York in August.

Jennings S. Cox, Jr., Met. E., 1887, of Santiago, Cuba, widely known in the United States and Cuba as a mining and metallurgical engineer, died in New York on August 31, 1913. For the past eighteen years Mr. Cox has been general manager of the Spanish American Iron Company and also of the Pennsylvania Steel Company's properties in Cuba. He was a member of the American Institute of Mining Engineers, of Alpha Delta Phi, and of the University Club of New York.

Joseph Lahey, E. M., 1887, died at his home in Brooklyn on June 20, 1913, after an illness of five days.

Hartwell Bishop, C. E., 1905, died on June 4, 1913, in Boston. He was a graduate of Harvard and Columbia, and at one time secretary of the Panama Commission. One of his students writes: "His untimely

death will be regretted keenly by those who served a part of their Camp Columbia 'apprenticeship' under him in 1905."

H. H. Struthers, E. E., 1909, died in New Orleans, on August 12, 1913. The funeral was held from his home at 132 West 129th Street, New York. He had been connected with the Bureau of Municipal Research in Cincinnati and with R. W. Hunt & Co., of New York. He was a member of the American Institute of Electrical Engineers.

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THE FIELD OF MECHANICAL ENGINEERING.*

BY WALTER RAUTENSTRAUCH.

Our present industrial life, with all of its complex relations and far reaching social and economic consequences, is so interwoven with the service of the mechanical engineer that perhaps it may be well to state how these conditions came to be, and to trace the rise and growth of that body of practices which, in its broadest sense, is termed mechanical engineering.

History is so replete with military achievements, and the rise and fall of nations as a result of the fluctuations of political and military power, events so spectacular and appealing to the emotions that many otherwise well informed persons are not aware of the important but unheralded happenings in the progress of the world, which have had far more influence in establishing our present conditions in life than the quarrels and wars of all the nations, and the laws of all the parliaments that have ever convened. For centuries, the production of food and the making of clothing were the chief concern of the people. Every householder made his own implements for tilling the soil, and utensils to assist the work of his hands, and the housewife spun and wove the cloth and provided the garments for family use. Headgear and footgear, clothing and finery, axes, knives, tables and benches, pots and kettles, the absolute essentials of existence, were made in the family circle for the use of the family. The family was thus both producer and consumer, and constituted the primary social unit of which tribes and nations were composed. This continued to typify the world's con-

* A lecture before the Freshmen engineering students of Columbia University, April 25, 1913.

dition until about 150 years ago, when it was discovered that combinations of levers, axles, and wheels, long used in the simple devices about the home and in the mines, could be utilized in producing the yarn and the cloth made by every housewife for the needs of the family. At the same time, the discovery that these machines could be driven by the prime movers then in use for pumping water in mines led to that remarkable combination of machinery and power which was the beginning of our complex manufacturing and industrial systems. Gradually, machines for producing and machines for driving were built and operated, not only for spinning and weaving, but to supplant, partially or completely, many hand processes. The small groups of men capable of constructing such machines labored earnestly and patiently to make these crude devices. There were no laws of machine design to guide them, nor theories of thermodynamics to point the way; men did not understand the elastic behavior of materials; nor, indeed, did the circumstances require the mastery of these sciences. They were concerned with the first move of an industrial revolution, the creation of machines that would work, the supplanting of hand labor by machines, the removal of obstacles which had retarded the progress of the world for thousands of years.

These crude yet operative devices, being constructed of whatever materials could be obtained and in such proportions as limited experience dictated, were made to run with varying degrees of success. As parts of machines broke in service, larger ones were substituted, and when certain combinations failed to function, other combinations were devised. This practice continued for many years, until certain men of genius, observing the many failures of machine parts, began to study them and gradually developed that body of principles now familiarly known as the resistance of materials. Others, observing the behavior of steam in engines, and familiar with the elementary laws of physics, began that series of analyses which today is represented in the science of thermodynamics. Still others, studying and classifying the motions of machines, formulated therefrom the foundation of that system which we now know as the science of kinematics. Thus was gradually introduced a body of laws and principles relating to the design, construction, and operation of machinery which enabled later

builders not only to construct more understandingly, but to extend the field and attempt constructions previously thought impossible. Hand in hand the mechanic and the analyist labored in the development of machinery and the perfection of processes which not only replaced hand labor in the making of articles then used, but made possible the creation of many new articles of necessity and convenience, tending to a higher plane of living.

The industrial era, therefore, is marked not alone by the mere substitution of machinery for hand labor, but by the invention and use of machinery which has given us many things of which our fathers did not even dream, and has raised the standard of living far beyond the fondest hopes of the most optimistic philosophers of that day. Machines have facilitated the making of many things not capable of production by hand processes, and of other things at a lower cost than by hand labor, so that today nearly all of the necessities and conveniences of our living are the products of machinery. Look about your own home: your house is built of bricks made by machines, the woodwork, plaster, nails, wall paper, pipes and fittings, rugs, carpets, curtains, linen, clothes, hats and shoes, soap and towels, gas and electric fixtures, cooking utensils, these and many others are the direct result of the operation of machinery. The food on your table, baked, toasted, cooked, and put into containers by machinery, kept in cold storage by machinery, and transported by machinery, so that the fruits, cereals, or meats of Florida, California, Europe, South America, and Asia are at your doors at a price within the reach of all. There has always been a going to and fro upon the earth; thousands traveled on land and sea and reached the uttermost parts of the world long before an engine ever ran; but that we might cross the Atlantic in a few days and on schedule time, that we might manufacture our goods in Pittsburg and place them in London in competition with European manufacture, that we might enjoy today the products of the earth reaped yesterday, required the design, construction, and operation of machinery. The machinery which makes possible all these things, completely changing the conditions of living in the past two generations, is the product of that group of men who served the people as mechanical engineers.

But mechanical engineering is more than the designing, building,

and operating of machinery. At the time when it was learned that machinery might be employed in substitution for hand labor, and that power could be used to operate this machinery, it was found desirable to collect such machines about the source of power. The grouping of machinery, and its housing in buildings, brought together many who, being concerned day in and day out with this one thing, gave rise to a new group in the social world, namely, the industrial workers. A new element, therefore, had to be considered, and those who had constructed the machines were now called upon to direct the labors of men engaged in their operation. The machine constructor, with his knowledge of forces and their applications to production, proved to be best qualified to control the men who must use these machines. The individual, isolated workman, who supplied his own capital, purchased the raw material, laid out the work, made the product, and sold the goods, gave way to the larger industrial unit with its subdivision of functions. Today, therefore, the making of every article of commerce represents the combined endeavors of capitalists and investors in industrial securities, operators and laborers of all classes, managers, distributors and carriers, the interests of which are the interests of the people, the importance of which is so great that nation will war with nation to protect the operation of its manufacturing institutions. So tremendous has been the growth of the industries founded on machinery that today in the United States the manufacturing industries employ over six million men and women who, through their earnings, directly support twenty-five million persons, or nearly one-fourth of our entire population. If to these we add those employed in transportation, which is also founded on machinery, we can account for as many more, and find nearly one-half of our population directly supported by the earners of wages in the manufacturing and transportation industries.

Not only has the use of machinery in production brought together large masses of people whose labor must be directed by the mechanical engineer, but it has also caused great aggregations of capital, making possible the possession of machinery, equipment, and materials to work upon. Because of his knowledge of the characteristics of materials and machinery, and his ability to judge their income-bearing value, the mechanical engineer has been entrusted with their

selection as well as their use and, therefore, has become intimately identified with the financial phase of the industries. The capital invested in the manufacturing industries alone in the United States amounts to the colossal sum of fifteen thousand million dollars, and the annual value of their products is over twenty thousand million dollars. Thus, mechanical engineering has become that profession which is concerned with materials, machinery, money, and men; its practice includes the design, construction, performance, and use of machinery in the creation of services such as light, heat, power, transportation, communication, and refrigeration, and in the manufacture of the articles of commerce too numerous to mention, and also the management of labor and the supervision of the economic conditions affecting the output and marketing of the products of the factory. While mechanical engineering is highly technical it is essentially an economic study. Just as the banker operates through the medium of bonds and stocks and is successful as he understands the laws which condition their value, so the manufacturer operates through materials, machinery, and men, and is successful as he understands the laws which condition the existence and prosperity of manufacturing institutions.

As the banker is interested in making money for his clients, so the mechanical engineer is interested in making money for the investors in industrial securities. That the medium of his operations is stocks, bonds, and mortgages, is incidental to the banker; so also that his medium is bricks, cloth, or steel rails, is incidental to the mechanical engineer. The practice of mechanical engineering is so broad and covers so many technical and commercial problems that it is impossible for any one man to become equally proficient in all. Accordingly, therefore, have arisen more or less natural divisions of practice, to any of which one having a broad understanding of all the related fields may confine his attention.

Let us consider some of these fields of service, beginning with the design of machinery, that practice of the profession upon which all subsequent activities are based. This is a work of creation, involving the devising of moving members, requiring an understanding of forces, both applied and engendered, and of their control and application to useful service; requiring a knowledge of the materials of which each part may be composed, their physical and chemical

characteristics and the processes and conditions of manufacture under which they are made. These problems, however, are not the sole field of the designer; he must also grasp the broader problem of economic production and demand. Machines are designed to sell, and the demand for them is extended just so far as they successfully compete with other machines in cost of operation. The questions of first cost, maintenance cost, and operating cost sometimes outweigh pure technological questions of functions and proportions. That the possession of a proposed machine or group of machines may be profitable is the first concern of the user. Hence, technological science, economics, and a knowledge of practical affairs, together point the way to successful issues in design.

Let us look farther to that field of practice which relates to the design of mills and factories, and is concerned with the gathering and housing of materials, machinery, and men, and their employment in the production of the necessities and conveniences of life. A far reaching outlook upon the technical and commercial phases of mechanical engineering is essential to the performance of this service. This practice involves in varying degrees of importance:

(1) An analysis of the product to be manufactured; what parts does it comprise, what materials possess the required physical, chemical, and perhaps magnetic properties demanded by each part? Are these materials adapted to forging or casting, must they be dried and baked, wetted and dried, or chemically treated? Of a variety of equally adaptable materials, what is the relative cost in the raw state; the cost of forming into parts? Whence must they be obtained? Are the freight charges high or low, and can we compete with others nearer that source of supply? These questions, and a host of others, all varying with different products, and no two solutions being alike, arise in determining the materials composing the parts and their processes of manufacture.

(2) What machines are adapted to the making of each part? What are their rates of output? Of a number of machines capable of performing the work, which is the most economically adapted to this particular industry, in first cost and in operating cost? Do conditions warrant the building of special machines? For a given quantity of product, how many machines of each kind will be required? What hand processes must be employed? A very great

number of questions arise in this connection, and, indeed, the conditions of the problem must be sought, for, unlike the mathematician, an engineer is perplexed not so much by the factors which appear as by the factors which do not appear and yet exert a strong influence on the results. The selection of machinery for processes, and the selection of processes to be done by hand tools is most absorbingly interesting, and is highly important in the problem of factory design.

(3) Next arise the problems of the succession of processes, the routing of materials through the plant, the location of machinery in the line of travel, the storage of raw materials and finished products, the selection of the best point for unloading and shipping. What processes require special housing; which must be located near the supply of power; which must be provided with heat; which create dust or otherwise interfere with neighboring processes; what processes must be on the ground floor; which may be on upper floors? A host of conditions arise which never admit of formulation but must, nevertheless, be considered in planning the arrangement of machinery and the location of all departments of the business. Provisions for safeguarding life and limb and conserving the health of workmen claim attention.

(4) What type of building is best adapted to the business; and can brick, stone, wood, and cement be readily secured at the place where the factory is to be located? What insurance regulations must be observed? Will it be cheaper to build this type of structure and pay a higher rate of insurance, or that more costly type and pay a lower rate of insurance? Are some processes so hazardous that they must be separately housed? What floor loads occur; what provisions for loading must be made? Is it cheaper to buy power or make it? Shall line-shaft drive or electric drive be employed? If electric drive, what system is best adapted to this particular installation?

Again, a deciding factor may be the location of the plant. Should it be near to sources of raw material or near the distributing center? Is the business largely export, requiring peculiar shipping facilities? How is the labor market in this locality, or in that locality? Are there many other factories to attract workmen to this district or to that district? What a number of factors must be considered! You

may be required to determine the best manner for your client to let his contract. Shall he buy the material and let the contractor erect, or shall he do the whole job himself? Shall he let the whole contract? How shall he best pay the contractor; shall he let the contract at a fixed sum, or shall it be actual cost plus a percentage? Shall it be a fixed percent. on cost, or a sliding scale of percentage, to influence the contractor to erect at minimum cost? Space does not permit the enumeration of more details of the service rendered by mechanical engineers in this most important phase of the world's work. Every factory and mill running today has given rise to problems of this kind, problems in which the best scientific knowledge and skill are required, in which the highest business ability is demanded.

Let us pass on to another field of service created and occupied by the mechanical engineer, a service closely allied to that which has just been considered, but differing from it in that it is concerned with the performance of plants rather than with their creation. I refer to the field of organization and management. Thanks to the mechanical engineer, the old type of mill and factory management is passing away, and the new type, popularly though erroneously called scientific management, is rapidly taking its place. That kind of management which is founded on driving the workmen, which depends upon force and fear, has no place in our enlightened civilization and is giving way to intelligent direction through knowledge and skill and a sense of equitable compensation for services rendered. This most important change in our industrial organizations is being wrought by the mechanical engineer, and is rapidly being extended to every field of human endeavor. I would that space permitted my considering in detail the many scientific and commercial problems with which this sort of service is concerned. I can mention only a few.

The scheme of organization and the plan of management is dependent upon the product of the plant. A factory engaged in making any particular article of commerce, or in creating a service, such as light, heat, or power, is concerned with a large number of detail operations, the coordination of which in any particular case depends entirely upon the product. In general, however, these functions must be provided for: (1) Purchasing raw material; (2) custody and distribution of raw material; (3) receiving raw material and

shipping finished product; (4) manufacture of parts, by machining, by casting, by forging, mixing, baking, or any number of processes; (5) designing of the product; (6) selling of the product, to which may be added testing, inspecting, and experimental investigation. Advice in civil and patent cases must be provided by a legal department, and perhaps many other functions may be necessary, depending upon the industry in question.

It is the duty of the mechanical engineer to determine all the detail operations which the business demands, and assign them to some individual for attention and execution; but more than this, he is required to provide means by which each man receives definite instructions on each job and reports to his superiors all the essential facts relating to the accomplishment of the work. The organization must be so perfected that when a job is to be put through the plant it passes to the planning department where it is analyzed into its component parts. It is assigned to a particular department, a time limit is set for making each piece, the pieces are started through the plant in such sequence that all parts reach the assembling floor in their proper order, and no delay occurs in assembly. Materials and parts must be so routed through the plant that every workman is effectively employed. Further, each piece passing through the plant must register a history of its progress; what raw materials were used in its making, and at what cost; how much labor was put on the piece, and at what price; what is the total cost for labor and materials? What machines were used in its making, and what charge for power and general investment should be made against it? These are very vital questions, and no business can continue in successful competition with others unless these things be known. Again, a number of different kinds of articles may be made in the same plant; if, for example, the plant cost $500,000, which at 5 percent. gives a yearly interest charge of $25,000 to be paid out of the profits of the business, the question arises, how much of the interest on this investment is chargeable to this product or to that product.

Thus we find that a most intimate association of commercial and technical problems occurs in this field of practice. The mechanical engineer, because of his knowledge of scientific facts relating to these matters and his ability to exercise sound commercial judgment, is best qualified to exercise supervision over such affairs and is, there-

fore, called upon to perform these functions in an almost untold number of industries.

Should a mechanical engineer choose to specialize in the field of power generation, transmission, and use, he again finds a most interesting field of labor, in which the highest type of scientific training and engineering skill is needed. The variety of the problems is as great as the number of uses to which power appliances are put. The appliances for pumping, for cooling, for air compression, for the utilization of steam, gas, and oil, can be designed, and their possible characteristics as units or as groups of units can be known only by a most thorough understanding of the chemical, physical, and mathematical sciences. Suppose that a central power station is to be erected for supplying electric current to a street railway. The questions arise: What are the probable load conditions; or what kind of load curve will it operate; will it be more economical to burn coal to make steam, or to use gaseous fuel, or oil fuel? What types of units, engines, boilers, feed-water heaters, condensers, electric generators, steam and electric auxiliaries, are best adapted to this plant? Perhaps gas producers, gas engines and gas-driven auxiliaries are best adapted; perhaps water wheels and water-power appliances. How are they best combined? Will it pay to provide apparatus for recovering a certain waste, or will it be cheaper to let it go? Many problems like this arise, the correct solution of which is most important to the commercial success of the installation. The management of a power station involves the same sort of organization and accounting as a factory. The cost of raw materials, coal, gaseous fuel, oil, or of water, must be accurately recorded; the interest on the investment and the depreciation of the machinery must be accounted for, in order to learn how much it costs to put a given quantity of current into the bus bars.

It will be seen that the field of mechanical engineering is broad. For which reason, the preparation for this service must embrace a group of subjects which is likewise comprehensive and fundamental. Whatever branch of engineering is undertaken, civil, mining, metallurgical, chemical, or electrical, successful practice requires an understanding of both commercial and technical phase of the use of materials, machinery, money, and men for producing the necessities and conveniences of our daily life.

ROCK-DRILL REPAIR COSTS.

BY C. K. HITCHCOCK, JR.*

In an endeavor to compile some accurate and definite information on the actual life of rock drills, and the cost of keeping them in repair, I have collected certain data, of which the condensed results are here given. These data were gathered through a period of two years, but are unfortunately incomplete, as the work was cut short by labor troubles. However, such results as were obtained are so significant as to lead me to believe that they may be of interest to others.

One great obstacle to obtaining data on the life of a rock drill is the manner in which repairs are made. I refer to the common method of taking worn parts from a machine, and, after truing them up, putting them into some other machine, which is in condition to use them. It is often possible to true up a part several times before having to throw it away, and each time this is done it may be put back into a different machine, so that in a comparatively short time the original parts of a drill may be widely scattered. Indeed, it is probably true that each one of a group of machines which are at work on the same job for two years will, at the end of that time, consist principally of new parts and parts taken from its mates, and will retain very little of its original self.

Fortunately, the keeping of the costs to be discussed in this article could be started with a group of 20 new drills. Of this number, five did not see enough service to make their record of value, whence the data here given relates to 15 machines. They were of a well-known make, having 2¾-in. pistons, and were put to work during the spring and summer of 1912. The records were kept by the month, and the total repair cost of each drill, including both labor and material but not including mountings or connections, was plotted at the end of each month on a chart against the total number of days, of two shifts each, during which the drill had worked from the time it was put into commission. From this chart then was scaled the cost for each drill for each period of 25 days, as recorded in Table I. The average of these amounts is shown at the bottom of Table I, and is plotted in Chart 1 by a solid line. The service varied a good deal,

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as will be seen, ranging from 150 days to 325 days each. This variation does not indicate poor service, but is explained by the fact that the drills were not all put to work at the same time, and also that the number of drills on hand was somewhat in excess of the actual number in use, so that some were always idle, whether in the repair shop or not. Good average results, therefore, were obtained for only 150 days, beyond which time the averages are incomplete and inconsistent, and lose all significance. It should be added that most of the smaller repair parts for the drills were made in the mine shops,

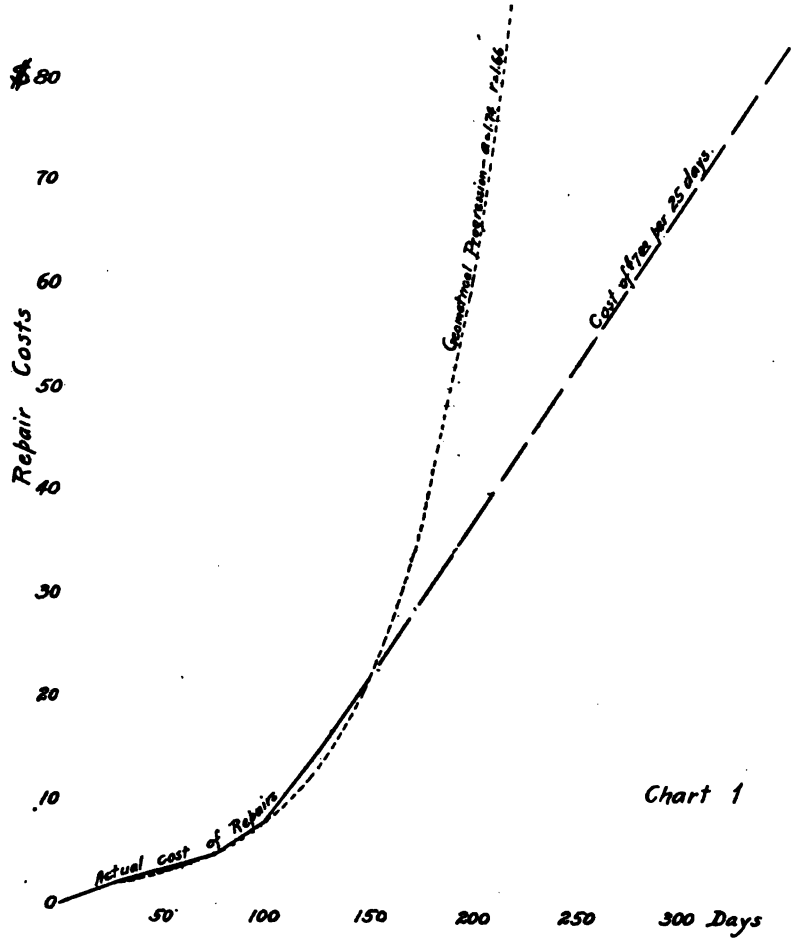
TABLE I. REPAIR COSTS OF 2¾-INCH DRILLS.

Drill.	Days in use.								
	25	50	75	100	125	150	175	200	225
A	$ 0.60	$ 1.25	$ 1.50	$ 2.40	$ 3.00	$ 7.05	$10.80	$11.40	$21.89
B	3.75	7.50	7.90	8.75	12.00	16.25	21.80	.....	.....
C	3.30	10.00	11.10	13.50	20.30	40.75	40.91	40.95	.....
D	.90	1.25	4.55	5.30	28.39	28.39	28.39	.....	.....
E	.15	.40	1.50	4.50	5.80	6.40	9.20	9.85	13.20
F	3.80	7.40	8.00	8.08	8.08	12.15	.....	.....	.....
G	.20	.50	1.10	4.75	8.00	14.95	16.20	20.08	27.20
H	.55	1.05	5.60	5.91	7.80	10.57	10.70	.....	.....
I	4.00	6.20	8.70	12.30	41.20	54.59	.....	.....	.....
J	.70	.70	3.50	4.70	8.29	8.45	.....	.....	.....
K	.60	1.00	1.50	21.00	41.00	42.10	43.36	52.40	.....
L	.55	1.00	2.20	9.10	12.00	12.30	21.30	.....	.....
M	.85	1.20	4.40	7.70	8.70	10.25	18.14	22.70	.....
N	3.65	4.10	4.85	5.05	8.50	50.50	52.01	.....	.....
O	2.55	4.35	4.65	5.20	11.20	14.60	14.75	.....	.....
Average	$26.15 $ 1.74	$47.90 $ 3.19	$71.05 $ 4.74	$118.24 $ 7.88	$224.26 $ 14.95	$329.30 $ 21.95	.....	.....	.....

but that the larger parts were bought from the makers of the drills. Also, when a machine was sent to surface, it was replaced at once by another, no serious attempt being made to keep the same machine in the same working place.

It is a curious fact, though probably only a coincidence, that the average repair cost for the first 150 days approximates closely the following geometrical progression, having 1.66 as a ratio: 1.74, 2.89, 4.80, 7.96, 13.22, 21.95. This progression is plotted as a dotted line on Chart 1, the solid line representing the actual repair cost. Obviously, if the repairs should follow the dotted line to, say, 200 days or further, the expense of keeping up these drills would be so great as to indicate that they had practically gone all to pieces, which, of course, is contrary to general experience. I believe, therefore,

that beyond 150 or 175 days the repair cost graph, if it could have been continued, would have become in time approximately a straight line, having such inclination as to represent a cost of $10 or over for each 25 days, provided all the machines were kept in commission.



This approximation is based partly on the fact that the actual repairs between 100 and 150 days were about $7 for every 25 days, and partly upon the performance of another size and type of drill, which I shall now discuss.

The drills of the second group were larger, having a 3⅛-in piston. Eight new ones were put to work in 1911, and the records were kept in the same way as for the 2¾-in. machines. But after two of the

drills had worked about 160 days, their cylinders cracked and they were put out of commission. The repair costs and service of the remaining six drills for two years is given in Table II, and is plotted in Chart 2. The graph thus produced is more irregular than that for the smaller drills, but a straight line joining the two ends aver-

TABLE II. REPAIR COSTS OF 3⅛-INCH DRILLS.

Drill.	Days in use.							
	25	50	75	100	125	150	175	200
P	$ 2.00	$ 2.50	$ 4.00	$ 5.40	$ 8.00	$ 19.00	$ 22.00	$ 22.60
Q	3.00	11.30	19.10	22.30	27.00	34.00	40.20	41.30
R	6.10	14.20	18.20	19.60	24.50	28.60	28.90	28.90
S	4.20	5.20	6.20	9.20	18.10	18.20	18.30	21.50
T	28.00	33.30	36.10	37.00	38.10	41.50	44.70	45.90
U	.50	4.30	4.90	11.00	12.80	14.00	17.80	18.20
	$ 43.80	$ 70.80	$ 88.50	$104.50	$128.50	$155.30	$171.90	$178.40
Average.	$ 7.30	$ 11.80	$ 14.75	$ 17.42	$ 21.42	$ 25.88	$ 28.65	$ 29.73

Drill.	225	250	275	300	325	350	375	400
P	$ 40.00	$ 64.20	$ 84.80	$ 88.10	$ 97.00	$ 99.50	$101.50	$102.00
Q	42.20	46.70	53.20	59.60	66.00	66.80	67.00	78.80
R	32.60	33.40	46.30	49.20	50.20	48.80	54.50	61.00
S	22.10	46.00	46.00	47.60	48.20	53.70	54.60	57.10
T	46.50	46.90	48.20	49.50	72.00	90.50	111.20	112.00
U	18.20	35.00	55.20	59.30	60.20	60.70	63.00	63.70
	$201.60	$272.20	$333.70	$353.30	$393.60	$420.00	$451.80	$474.60
Average.	$ 33.60	$ 45.37	$ 55.62	$ 58.88	$ 65.60	$ 70.00	$ 75.30	$ 79.10

Drill.	425	450	475	500	525	550	575	600
P	$115.50	.....	.....	.....	.....	.....	.....	.....
Q	79.50	.....	.....	.....	.....	.....	.....	.....
R	75.00	$ 76.70	$ 77.30	.....	.....	.....	.....	.....
S	60.20	62.70	62.70	$ 63.00	$ 64.00	$ 67.70	$ 78.10	$ 78.30
T	113.80	113.80	114.00	114.50	.....	.....	.....	.....
U	64.00	70.00	73,70	74.40	98.80	.....	.....	.....
	$508.00	.....	.....	.....	.....	.....	.....	.....
Average.	$ 84.67	.....	.....	.....	.....	.....	.....	.....

ages the irregularities fairly well and represents a cost of practically $5 per 25 days. Of course this is hardly a fair comparison, and for the purposes of this discussion, it would have been desirable to have had the drills repaired and kept in commission. The immediate cost would have been between $60 and $80, with a resulting average increase of $8 or $10 at the 175-day period. How much of this increase would have shown as an increase throughout the remainder of the graph, is of course uncertain, but probably enough to have brought the average beyond 175 days up to $10 for every 25 days.

Again, from other data too incomplete to give here, obtained from such of another group of drills of the same size and type as had been in commission for from three to five years, the repairs amounted to $7.50 every 25 days. This rate, of course, is based on the best

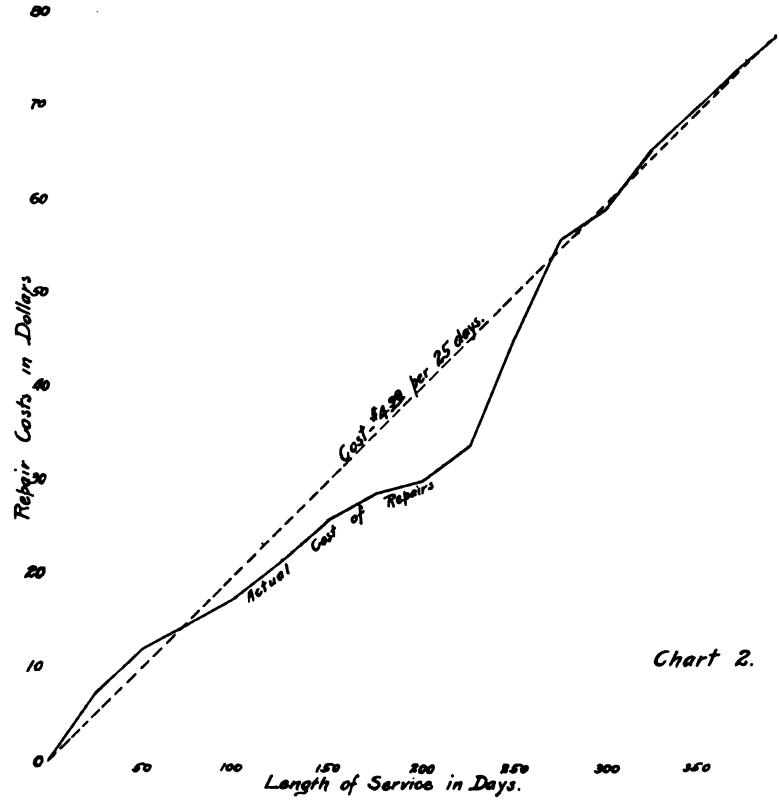


Chart 2.

machines of the lot, the poor ones having been discarded. If all had been kept at work, there is evidence that the cost would have been nearly double.

The practical application of such data as here given should be obvious. For instance, having obtained or assumed the average repairs for a certain lot of machines at work on a given job, and having plotted it on a chart, it would then be an easy matter, even for the repair man, to see how things were going, simply by plotting the record of each individual machine, month by month, alongside the average. Some machines, at times, will show up badly

beside the average, for some good cause, while others will compare poorly from some inherent defect, and will be a constant source of expense. By a study of the chart, in connection with the care of the drills, economy and efficiency could both be served, either by culling out the worst offenders, or by giving them such a thorough rejuvenation as would tend to cut down their maintenance expense.

REINFORCED CONCRETE STUDIES.[1]

II. THE STANDPIPE.

BY J. K. FINCH.

Structures used for storing liquids are of several types — reservoirs, tanks, elevated tanks, and standpipes. These terms are used somewhat indiscriminately and, while there can be no doubt as to the definition of an elevated tank, the line between standpipes and tanks is not so clearly defined. In the present article the word standpipe means a circular tank of which the height exceeds the diameter. We shall discuss primarily the reinforced concrete standpipe, but as a circular tank is simply a section of vertical pipe, the same principles, properly modified, apply also to the design of circular tanks.

GENERAL.

Historical.—So far as we have been able to learn, the first reinforced concrete standpipe built in this country was that designed by Wm. B. Fuller in connection with the filtration plant at Little Falls, N. J., in 1899.[2] In 1903, standpipes of 93,000 and 118,000 gal. capacity were built at Millford, Ohio, and Fort Revere, Hull, Mass. In 1904, the Attleboro, Mass., pipe was built, having a capacity of 1,500,000 gal., which still remains the largest tank in which the height exceeds the diameter. Since 1904, a number of tanks have been built, some of which have been described in the technical press. The *Engineering News* of July 27, 1911, p. 124, gives a list of a number of these structures, with references, and the table on the following page gives also the principal dimensions of a number of tanks and standpipes.

Advantages.— The principal advantages usually stated as reasons for the substitution of reinforced concrete for the widely used steel tank or standpipe are two: (1) Economy, in both first cost and maintenance, and (2) adaptability to architectural treatment. As a rule, the first expectation has been fulfilled, and, although it is prob-

[1] The first article of this series on "The Hollow Dam of the Buttress Type" appeared in Vol. 34, No. 3 of the QUARTERLY, April, 1913.

[2] See *Trans.* Am. Soc. C. E., Vol. 50, p. 454. No details given.

TABLE I. DIMENSIONS, ETC., OF CONCRETE WATER TANKS.

Type.	Location.	Capacity, Gal.	Height, Ft.	Diameter, Ft. Inside	Thickness of Shell, Bottom. In.	Thickness of Shell, Top. In.	References.
S	Little Falls, N. J.....	25,260	43	10	15	10	*Trans.* A. S. C. E., 50, p. 454.
S	Milford, Ohio	93,000	81	15½*	9	5	*Eng. News*, Feb. 25, 1904.
S	Fort Revere, Hull, Mass....	118,000	50	20	6	3	" " Dec. 29, 1904.
S	Attleboro, Mass.....	1,500,000	100	50	18	8	" " Feb. 21, 1907.
T	Hampton, Va.....	66,000	16	26½	12	12	*Trans.* A. S. C. E., 50, p. 433.
T	New Haven, Ct.....	375,000	25	50	18	18	*Eng. News*, Feb. 20, 1908.
S	Empalme, Mexico.....	475,000	90	30	10	5	" " Dec. 9, 1909.
S	Bridgewater, Mass.	413,000	78	30	20	12	" " July 27, 1911.
S	Westerly, R. I.....	650,000	70	40	14	14	*Trans.* A. S. C. E., Sept. 1911.
T	Sonora, Mexico.....	10,000	12	12	6	6	*Pro.* A. Ry. Eng. Assoc., 1912.
E T	Anaheim, Cal.....	200,000	38	32	5	3	*Eng. Rec.*, Aug. 24, 1907.
S	Waverly, Ohio.....	120,000	80	22	12	6	*Concrete Eng.*, July 19, 1911.
T	Lincoln, Me.....	108,000	16	32	8	8	
E T	Cuba	184,000	24.75	34	9½	8	*Eng. News*, April 30, 1908.
E T	San Francisco, Cal.....	32,400	20	17*	2½	2½	*Eng. Rec.*, Jan. 4, 1910.
S T	Niagara Falls, N. Y.....	.....	70½	75	24	24	
S	Fulton, N. Y.....	930,000	100	40	18	18	*Eng. Rec.*, Jan. 10, 1914.
T	San Francisco, Cal.....	750,000	36	60	..	..	*Eng. News*, Dec. 11, 1913.

S=Standpipe. T=Surface tank. ST=Surge tank. ET=Elevated tank. * Outside.

able that a well designed concrete standpipe will cost fully as much as a steel pipe, concrete tanks usually cost slightly less than steel, and the maintenance cost is small. The life of a structure of this type is unknown. The Waverly standpipe is said to have cost 3.75c. per gal., and had a capacity of 120,000 gal.; the Westerly standpipe cost $18,000, or 2.75c. per gal. for 660,000 gal.; the Fulton, N. Y., $24,335, or 2.6c. per gal. for 930,000 gal.; and the Attleboro pipe, 2.25c. per gal. for 1,500,000 gal. On the Attleboro standpipe, the concrete in place cost $14.00 per cu. yd. (Materials, $8.70; mixing and placing, $2.60; forms, $2.70.) Bending and placing the steel cost $9.00 per ton and a large number of Crosby clips were used at 36c. each. The complete itemized cost of the Westerly standpipe is given in *Trans.* Am. Soc. C. E., Vol. 74, p. 390.

The adaptability of concrete to architectural treatment is unquestioned, and such structures as the Westerly standpipe show how pleasing in appearance a structure of this kind may be made at a small extra cost. See Fig. 2, in which a similar treatment is used. Standpipes and elevated tanks are almost invariably placed on high ground where they may be seen from afar, and should most certainly be designed for artistic effect as well as for safety and economy. Unfortunately, however, while a pleasing form can be obtained, most tanks have been marred by dark moist spots or by splotches of efflorescent salts on their exterior surfaces. By proper design these objections can be avoided, but few tanks built to date have been absolutely free from them.

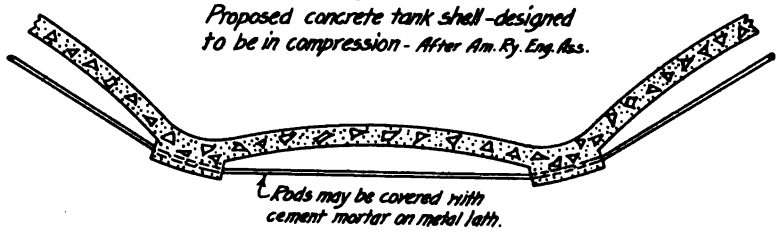
One other advantage of concrete over steel that is of considerable importance is its suitability for tanks to hold impure water or other liquids that would corrode iron. The Attleboro standpipe replaced a steel structure from which as much as two tons of rust were said to be taken annually, due to the large amount of carbon dioxide in the water. It is also claimed that the water in concrete standpipes seldom freezes and the dangers due to this trouble are thereby avoided.

Disadvantages are principally those due to leaks and discoloration and the danger of flaking off of wet concrete in cold climates. There is also an uncertainty as regards the life of tanks of this kind, due to the possible corrosion of the steel, but this need not cause any apprehension in tanks designed as indicated in this paper.

ELEMENTS OF DESIGN.

It is evident from the above that a standpipe, to be considered entirely successful, must not only not leak, but must not show damp spots or discoloration. No pipes yet built have allowed any important loss of water by leakage, and a tank which, for all practical purposes, is watertight is a comparatively simple structure to build. When it is necessary, however, to obtain absolute watertightness, a number of difficulties are encountered. These are due somewhat to the form of construction used, in

- Fig 1 -


Proposed concrete tank shell - designed
to be in compression - After Am. Ry. Eng. Ass.
Rods may be covered with
cement mortar on metal lath.

which the shell is in tension, and in one or two cases the engineer has apparently given up all hope of making a tight concrete tank and has used the concrete simply as a covering for a steel tank.[1] The American Railway Engineering Association has suggested a form, shown in Fig. 1, which places the shell in compression and thus does away with one of the difficulties.

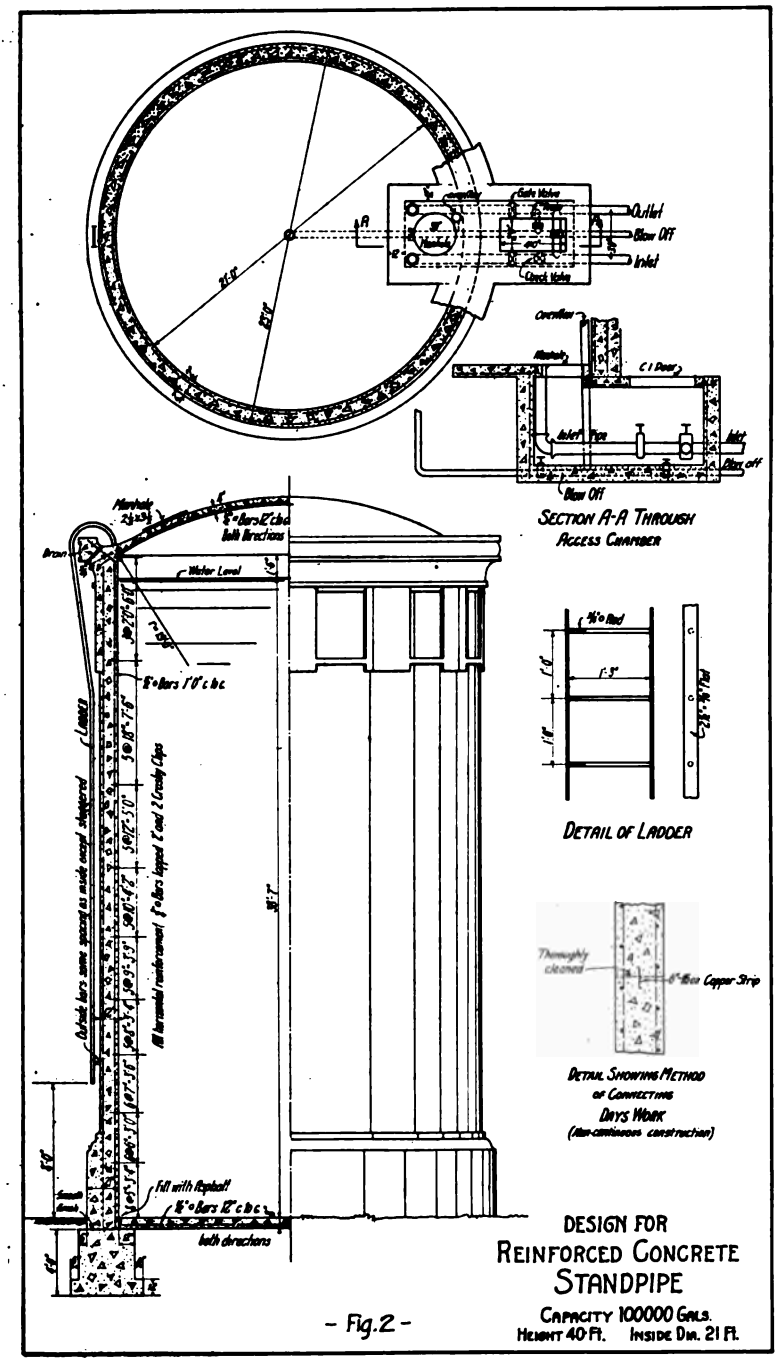
An inspection of Table 1 will show that a great variation exists in the thickness of concrete wall used, and in the past this has been mainly a matter of judgment, with a tendency to use a very thin section. The various methods of design that have been used for the walls are as follows:

1. Design the steel to take all the hoop tension and use an arbitrary thickness of concrete simply as a filling between the steel bars. For concrete pipes, for example, the concrete is usually made 1 in. thick for each foot of diameter.

2. Design as above, but use very low tensile stress in the steel.

3. Design steel as in 1, but use sufficient thickness of concrete so that the combined material will also take the hoop tension with a moderate stress in the concrete.

[1] *Trans.* Am. Soc. C. E., Vol. 70, p. 335; also *Eng. News*, Oct. 20, 1910, p. 403.


Outlet
Blow Off
Inlet
Section A-A Through Access Chamber
Detail of Ladder
Detail Showing Method of Connecting Days Work
(Non-continuous construction)
Design for Reinforced Concrete Standpipe
Capacity 100000 Gals.
Height 40 Ft. Inside Dia. 21 Ft.
- Fig. 2 -

Method 1 is satisfactory where artistic qualities are unimportant. Leakage will occur, but not in sufficient amount to make the loss important. Method 2 is an attempt to prevent excessive stretching of the steel, due to the hoop tension, and the consequent formation of vertical cracks in the concrete, due to the fact that it will stretch very little without cracking. Various unit stresses have been recommended, varying from 14,000 down to 7,500 lb. per sq. in., and while this practice of using a low tensile stress is doubtless correct, it does not entirely prevent the formation of vertical cracks. The method outlined in 3 was first proposed by H. B. Andrews in a paper presented before the Boston Society of Civil Engineers, in 1910, entitled "A New Theory for the Design of Reinforced Concrete Reservoirs."[1]

It is evident that a reinforced concrete shell, such as occurs in a circular tank, is in tension and that so long as the total tension is not too great it will be carried jointly by the steel and the concrete in a manner similar to a longitudinally reinforced concrete column, the unit intensities of stress being proportional to the moduli of elasticity of the respective materials. Thus in a reinforced concrete tank, by using the proper area of steel and proper thickness of concrete, the total hoop tension may be carried in part by each of the materials, the stress in the steel being n times that in the concrete, irrespective of their areas, and no vertical cracks due to stretch will develop. Obviously, since we should in this case be counting on the concrete to take tension, a very low unit stress should be used for the concrete, and that in the steel will be only 12 or 15 times greater; hence an exceptionally heavy and costly construction would result.

If, however, we place sufficient steel in the form of hoops to take the entire hoop tension at a safe unit stress, the "ultimate safety" of the structure is assured. Furthermore, if we design the concrete so that it, combined with the steel, will also take the entire tension without being unduly stressed, vertical cracks will be avoided and, as the ultimate safety is amply provided for by the steel alone, we may adopt a high unit stress for the concrete. This method leads to a reasonably economical design and

[1] Abstracted in *Eng. News*, July 27, 1911, p. 122.

has, since Mr. Andrews first proposed it in 1910, been adopted in several structures.

Formulas.— As stated above, if we consider ultimate failure we cannot rely on the concrete to take any tension, and the area of steel in sq. in. per ft. of depth, from the usual formula for hoop tension, will be

$$A_s = \frac{w x R}{f_s} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (1)$$

where

w = weight of a cubic foot of the liquid contained in the tank (62.5 lb. for water).

x = depth of liquid in feet.

R = radius of hoops in feet.

f_s = working stress in steel in lb. per sq. in.

The spacing of different layers of bars, in inches, will be given by:

$$d = \frac{12\,a\,z}{A_s} = \frac{12 f_s a z}{w x R} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (2)$$

where a = area of one bar in sq. in. and z = number of vertical rows of bars.

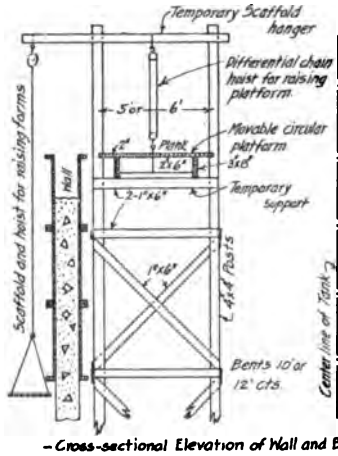
Since the hoop tension per foot of depth $= wxR$, and the stress taken by the steel will be $n f'_c A_s$ (where n = ratio of the moduli of elasticity of steel to that of concrete, and f'_c = allowable intensity of tensile stress in the concrete in lb. per sq. in.), while the stress taken by the concrete = area of concrete $\times f'_c$ or $(12t - A_s)$ f'_c where t = the thickness of shell in in., we have, equating the above values and simplifying,

$$t = \frac{w x R - (n - 1) f'_c A_s}{12 f'_c} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (3)$$

giving the thickness of shell required.

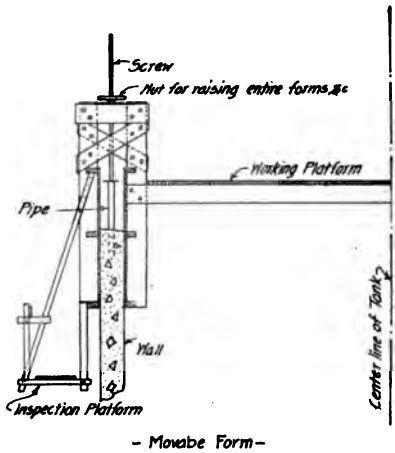
Unit Stresses.— Mr. Andrews assumed that, with reinforcing, a 1.1.2 gravel concrete in tension would fail at 400 lb. per sq. in. To justify this figure, as he could find no tests of concrete in tension, he had several tests made at the Watertown Arsenal of 4-in. square specimens. These showed average ultimate strengths, in lb. per sq. in., at 60 days, of 113 for 1.2.4 concrete, 202 for 1.1½.3, and 281 for 1.1.2. He further assumed, however, that

these figures could be increased 25 percent. in large-sized specimens, and further increased 10 percent. for the effect of reinforcing steel, these assumptions being made for the following reasons: The first "because large-size specimens in compression usually showed about this percentage of increase over small ones," and the latter because "in an unreinforced specimen the failure will take place where the first crack develops," while in a reinforced specimen "the strain would be distributed nearly equally over the entire section by the reinforcing steel and the failure would take



-Cross-sectional Elevation of Wall and Bent-

-Fig 3-



- Movabe Form-

-Fig 4 -

place at a plane in which was located the resultant of a number of weaker areas of concrete." Editorial comment on Mr. Andrews' article in the same issue of the *Engineering News* stated that "we know of no extensive tests that justify either of these increases."

In selecting a unit stress for the 1.1.2 concrete used, Mr. Andrews took 290 lb. per sq. in., stating that this was well within the assumed ultimate of 400 lb., which latter figure he justified by increasing his test figure of 281 lb. by 25 and 10 percent., as above, which gave him 386 lb. or nearly the assumed figure. He used this figure, with 12,000 lb. per sq. in. for the steel, in the design of the Waltham, Manchester, and Lisbon Falls standpipes.

In a tentative report of the Water Supply Committee of the American Railway Engineering Association,[1] a steel stress of 10,000

[1] *Pro.* Am. Ry. Eng. Assoc., 1912, Vol. 13, p. 402.

lb. per sq. in., and 300 lb. for the concrete, is suggested, the committee stating that "we do not say that the concrete will not break under a stress of 300 lb. although experiments indicate that the high grade of concrete used in tank construction may have an ultimate tensile strength of 400 or 500 lb. per sq. in." It was also stated that 128 tanks of 10,000 gal. capacity each, built by the Montezuma Copper Co., Sonora, Mexico, showed absolutely no sweating or leakage, the steel being designed for 11,400 lb. and the concrete being stressed only 63 lb. per sq. in. These are, of course, only small tanks, and this low concrete stress, which we should expect to give eminently satisfactory results, would hardly be justified in larger construction.

In a recent article in the *Trans.* Am. Soc. C.E.[1] a reinforced concrete reservoir of 4,250,000 gal. capacity is described. This tank is 153.5 ft. diameter and 25 ft. deep. Mr. Andrews' method was used, with the same unit stress of 290 lb. in the concrete and a slightly higher steel stress. The mixture was 1.1½.3, with ¾-in. limestone.

Mr. Andrews' assumption that the use of reinforcing increased the capacity of concrete to take tension without cracking was first proposed by Considere, but it was later shown that cracks actually developed at a stress about the same as that causing failure of plain concrete. M. Considere determined the stress in the steel by measurements of its elongation, and then assumed the concrete to carry the rest of the load. This is, of course, true only while the stress in the concrete and steel is uniform between points of measurement. Thus, even when the concrete has cracked entirely through in places, the remaining portions would possess considerable tensile resistance and would modify the value of the coefficient of elasticity of the steel, although the tensile value of the concrete would really be zero.

While the increases made by Mr. Andrews are not justified, his tests seem to be lower than could be generally expected for well made concrete, such as should be used in work of this character. It is to be regretted that no extensive tests of reinforced concrete have been made which would enable us to obtain a truly reliable unit concrete stress. Economy demands using a low factor of

[1] Dec., 1913, p. 2133.

safety, of 1½ to 2, and it is therefore very important to have a safe ultimate strength on which to base our estimates. A few tests have been made on plain concrete in tension, but the only tests on *reinforced* concrete in tension, except those mentioned by M. Considerè, so far as we know, are a few tests made at Columbia University on a 1.3.5 concrete made of ¾-in. trap rock with percentages of steel varying from 0.68 to 4.26 percent.[1] The test pieces were 6 x 6 in., and specimens were broken at an age of six months. They gave an average figure of 205 lb. per sq. in., and showed no variation with the amount of reinforcement.

Turneaure and Maurer[2] give a number of tests of plain concrete in tension which show a large variation in results depending on age, mix, and manufacture, as would be expected. Standpipes require the best quality of material and workmanship, and judging from the few tests available the following values appear reasonable for broken-stone concrete.

Mix.	Age, Days.	Ultimate Strength, Lb. per sq. in.
1.1.2	30	300 to 400
	90	400 " 500
1.1½.3	30	250 " 350
	90	350 " 450
1.2.4	30	200 " 300
	90	300 " 400

The tensile strength adopted in any case should depend upon how soon the structure is to receive its load, but it would seem safe to use 150 lb. per sq. in. for 1.2.4 concrete, 200 lb. for 1.1½.3, and 250 lb. for 1.1.2.

Field Joints.— It has been shown that concrete, in setting, shrinks from 0.02 to 0.05 percent., depending to a large extent on the amount of water used in mixing, being greater for a wet mixture. The problem of making a satisfactory joint between the successive layers of concrete in a standpipe is therefore not only that of connecting new concrete to old, but, due to the bond between the concrete and the vertical steel, which soon becomes sufficient to prevent the mass from settling as it shrinks, a fissure is liable to occur between the successive day's work, no matter how carefully

[1] C. E. thesis No. 176, Columbia University.
[2] "Principles of Reinforced Concrete Construction," p. 16.

the joint has been cleaned. The only remedy is, of course, to pour the wall continuously, and wherever possible this should be done. When this is not possible, a copper strip should be inserted in the joint as shown in Fig. 2; this precaution, together with care in preparing the surface of the old concrete before the new is deposited, should assist greatly in diminishing trouble from this cause.

Distribution of Hooping Metal.— Some engineers have made a point of placing all the hooping steel in one vertical row, believing it advantageous in "causing each hoop to be equally stressed," and thus carry its proper portion of the load. This may be true to some extent, but we can not see any great advantage in this method of placing the hoops. Large-sized bars are required, which are difficult to bend and erect; very close spacing of the rods is also required at the bottom, involving a difficulty in getting a strong bond between the concrete and the steel, due to failure of the concrete to fill in closely between the bars. This feature caused trouble at Attleboro. We believe that a reasonable amount of vertical steel, well distributed, will be of much greater assistance in causing a proper distribution of stress, and that the hoops should be placed in two or more rows.

Placing the steel in at least two vertical rows, near the inside and outside of the shell, also is of advantage in case any secondary stresses arise, due to slight changes in the curvature of the tank. Such changes should not occur, and reflect poor construction, but the importance of keeping the tank truly circular is well brought out in the following table, which also shows that variations in curvature affect the stresses in the larger tanks, where they are difficult to eliminate, to an increasing extent.

Radius of Tank.	Variation in Radius of Curvature.	Corresponding Range in Tension in Steel.
Feet.	Feet.	Lb. per sq. in.
25	23.0 to 27.2	12,860 to 16,200
50	42.8 " 60.1	11,950 " 19,100
100	74.9 " 150.5	5,910 " 21,100
200	120.2 " 632.0	5,820 " 44,500

Column 2 gives the variation in the radius of curvature due to an assumed possible variation of ½ in. in the middle ordinate of

a 10-ft. chord. The last column gives the corresponding range in unit tensile stress in the steel, computed on the basis of an average tension of 14,000 lb. per sq. in.[1] These figures are, of course, only relative and assume that no adjustment of the tank takes place.

Splices.— It would seem sufficient simply to lap the hoops some 40 diameters, and wire them together at joints, so arranging the bars that the joints would not occur vertically one above another. To facilitate the erection of the steel, however, and as an additional precaution against slipping, it has become customary to use two or more Crosby clips at each joint. These clips are of the same type as used in splicing cables, and hold the bars securely together.[2]

Ice Stresses.—It has generally been found that little or no ice forms in covered concrete tanks, nor in tanks in which there is a continual variation in water level. Theoretically, no hoops would be required at the top of the tank, except those required to take up the thrust from the roof, if a conical or dome roof is built. Hoops, however, are generally used throughout the full height of the tank, and are placed at the top with the intention of resisting any pressure that may occur from formation of ice, and to bind the structure together, although a computation for spacing at this point is seldom made.

Vertical Reinforcement.— One feature of vertical reinforcement was mentioned above. There must certainly be enough to support the hoops at the proper spacing in advance of the concreting. In the method of intermittent construction generally adopted, special supports, such as angles, pipes, or tees, have been used to support 4 to 7 ft. of steel, as required for each lift. The introduction of large-size vertical steel shapes or bars cuts down to some extent the effective area of concrete for taking tension, and it would seem preferable to use a large number of small rods, say ½-in., for supporting and holding the hoops in place, instead of steel shapes and pipes; the latter are certainly disadvantageous, while the former aid in distributing the stress throughout the structure, bind the shell firmly together, and are more advantageously placed to take up temperature stresses which are liable to occur when the tank is

[1] *Eng. News,* April 25, 1912, p. 770.
[2] For tests, see *Pro.* Am. Soc. C. E., Dec., 1913, p. 2140.

empty. The total desirable amount of vertical steel is hardly subject to computation, but 0.3 to 0.5 percent. is usually adopted for temperature reinforcement, and would probably be ample for support.

Connection between Sides and Base.— It has been the almost universal custom to turn up the floor or bottom reinforcement into the sides of the tank, but this practice frequently gives rise to the formation of a horizontal crack near the bottom of the tank. This is doubtless due to shear, caused by the lower portion of the tank acting as a cantilever, while the stretching due to hoop tension in the adjoining portions above is restrained. After a study of existing designs, we conclude that there is no reason for carefully connecting the sides and bottom of a tank; in fact it would be better to build them entirely separate, making the tank simply a vertical section of pipe resting on, but independent of, the base. This would obviate the difficulty mentioned above. The joint would, of course, have to be investigated for upward pressure, due to wind or a possible upward hydrostatic pressure, but it will have, in the majority of cases, an ample positive pressure. This method was followed in the design shown herewith.

Discussion of this detail with several engineers engaged in work of this character disclosed that this feature was first proposed by Mr. Wm. Mueser, of the Concrete-Steel Engineering Co., in a discussion printed in the *Trans.* Am. Soc. C.E., Vol. 74, p. 392, and that a similar joint was described by G. L. Bilderbeck, Supt. of Construction, U. S. War Department, in *Engineering News,* Sept. 7, 1911, p. 297. It was further found that R. D. Johnson, hydraulic engineer of the Ontario Power Company, had made experiments with this type of joint and had actually constructed the No. 2 surge tank at Niagara Falls on this principle. This tank is 76.5 ft. high and 79 ft. diameter, and was built as a section of concrete pipe resting on a perfectly flat base. It is understood that, before placing the wall concrete, a thin layer of clay was placed on the base directly under the wall; this simple joint has given entire satisfaction and no cracks have developed in the structure. The *Engineering Record,* Jan. 10, 1913, published an article by Mr. Mueser in which he describes the use of a sliding joint, which he has patented. Mr. Mueser uses thin copper strips,

coated with graphite, under the wall, and an asphalt joint, but we believe that the strips are unnecessary. A 750,000-gal. tank recently erected in San Francisco [1] was also successfully built with a so-called "sliding base."

Wind Pressure.— The investigation for overturning moment due to wind, and the resultant base pressure on the wall, is simple and may be made in the following manner:

Let p = maximum wind pressure in lb. per sq. ft., usually taken as 30 to 40.
H = total height of standpipe in feet.
r = inside radius in feet.
R = outside radius in feet.
w = weight of cubic foot of concrete in pounds.
s = maximum stress at bottom of standpipe due to wind, in lb. per sq. in.

Then, using the factor of $\frac{2}{3}$, which value has been shown to be required for cylindrical surfaces, the total pressure due to wind will be $\frac{2}{3}\ pH \times 2R$, and the overturning moment will be this value multiplied by $\frac{1}{2}H$, or $\frac{2}{3}pRH^2$. This produces tension on one side of the base and compression on the other, and, since the resisting moment of the tank about its base $= sI \div R$, (I being the moment of inertia),

$$= \frac{144\pi S\,(R^4 - r^4)}{4R} = \tfrac{2}{3}pRH^2, \text{ we have}$$

$$s = \frac{pR^2H^2}{54\pi\,(R^4 - r^4)} \qquad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (4)$$

The direct compression due to weight of walls and roof load, plus s, should not exceed, say, 200 lb. per sq. in. Also, the same figure, minus the possible hydrostatic pressure due to the head of water in the tank, and minus s, should be a positive quantity.

Foundation and Bottom.— In many cases a solid foundation bed of concrete 3 or 4 ft. thick has first been placed, on which a final 6-in. floor, reinforced in both directions with ½-in. bars at 12- to 24-in. centers, has been laid. This construction is costly, but is doubtless the best for high tanks and in all cases when the foundation material is liable to compress or settle. If the foundation

[1] *Eng. News*, Dec. 11, 1913, p. 1204.

material is hardpan or well compacted gravel and sand, the construction shown in Fig. 2 may be used for small pipes. It should be remembered that the floor is under a very heavy load, and any settlement will doubtless cause cracking, resulting in leakage and danger to the foundation. The foundation should be so designed as to be safe beyond question, and reasons of economy should not be allowed to influence this part of the structural design.

Roof.— This is generally in the form of a dome, and in most cases it has been found cheaper to use a Gustavino tile instead of a concrete dome. The former can be erected with little or no centering, while the latter rquires a costly center which, added to the cost of the reinforcing and finishing, will generally exceed the cost of tile. In the computations which follow a brief investigation of the concrete dome is given.

Waterproofing.— In almost every case it has been originally planned to use a concrete of such density that no waterproofing would be required, but in the end it has been necessary to resort to the use of some process — generally a soap and alum wash. In at least one case the waterproofing compound was placed in the concrete itself. Col. Wm. M. Black, in building two tanks in Cuba,[1] used a concrete having " 10 percent. greater amount of cement than required to fill the voids in the sand," and before mixing " added 15 lb. of powdered alum and 6 lb. of powdered castile soap to each barrel of cement."

The interior surface of the Attleboro standpipe was treated with a " Sylvester " solution as follows.[2] The wall was first thoroughly cleaned and dried; then a pure castile olive-oil soap solution (12 oz. to the gallon of water) was applied boiling hot. Twenty-four hours later, when the wall was dry, a solution of alum (2 oz. to the gallon of water) was applied at ordinary temperature. The soap and the alum washes were thus alternated for four coats each. This process forms an insoluble mixture which soaks into the concrete for a slight depth, and doubtless aids in preventing sweating, but proper design and construction, combined with a dense concrete, must be relied upon and will give a watertight tank.

[1] *Trans.* Am. Soc. C. E., Vol. 64, 1909, p. 540.
[2] *Eng. News,* Feb. 21, 1907, p. 212.

Forms and Construction.

Two types of forms have been developed, which can be made of either steel or wood: sectional or movable.

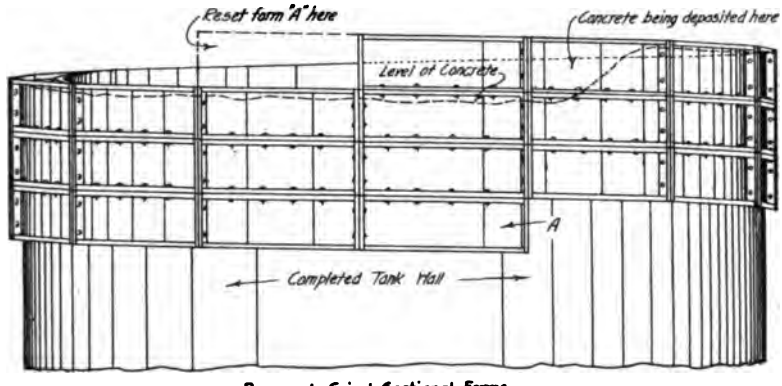
Sectional forms have generally been employed where no attempt has been made to work continuously. They are usually made 3 or 4 ft. high and in sections 6 to 8 ft. long, so that they can be handled by two men. The depth is made equal to the expected daily progress, and the best records have seldom exceeded 3 ft. per day. The forms for the Westerly standpipe were made 3 x 8 ft. of ⅛-in steel, having 1½ x 1½-in. angles on all four edges, and two intermediate stiffeners. A tower for hoisting concrete is generally constructed outside the standpipe, with a hopper at the top, the concrete being distributed from this point by wheelbarrows or a pipe. A working platform is carried up inside the standpipe for handling and cleaning forms, erecting steel, etc., and it has also been found necessary in several cases to "line up" the inside forms by braces to the framework supporting this platform. Fig. 3 shows a construction similar to that used on the Westerly standpipe.

For continuous concreting, a movable form has been successfully used at Fulton, N. Y., where a standpipe 100 ft. high has recently been constructed.[1] In this case the working platform was supported by the inside forms, which, in turn, were rigidly connected to the outside forms, as shown in Fig. 4. Both forms and platform were moved continually by a fixed nut and movable screw arrangement resting on pipe supports set in the concrete. The forms were 5 ft. 4 in. deep, and the standpipe walls were satisfactorily completed in a little over 20 days, working in three 8-hour shifts. Although this is probably the most economical method of construction, as it saves the cost of the inside tower and also the labor in resetting forms, two points demand investigation before it can be stated that it is the best method. First, the effect of moving forms over the surface of green concrete might be expected to injure the surface, at least, and to cause some flaking. Secondly, the use of vertical pipes in the wall, for supporting the entire forms and platform as above mentioned, is undesirable since the constant vibration and movement due to the tightening of the

[1] *Concrete-Cement Age*, Feb., 1914, p. 53.

screws and shifting of men and material on the platform would probably destroy the bond between the concrete and these pipes.

We suggest, as a possible design for forms, the spiral type shown in Fig. 5. These forms, made in small sections, combined with a movable platform similar to that shown in Fig. 3 would allow continuous construction, and at the same time overcome both the



— Proposed Spiral Sectional Forms —
— Fig 5 —

disadvantages of the movable type. One set of special tapered forms would be necessary in starting the construction from a horizontal base course. The placing of the concrete would proceed in a spiral layer, 1 to 2 ft. deep, so arranged that sufficient time would elapse between the layers at any point to allow the concrete in place to settle but not to set.

Outline of a Design.

As an example of the application of the above formula, a brief outline of the design of a standpipe to hold 100,000 gal. will be given. This capacity may be obtained with several varying heights and diameters, but in any one case the ratio between height and diameter is generally fixed by local conditions and cost.[1] The common ratio of ½ will be used.

$$Q = 5.82\, D^2H = 5.82\, r^2H^3, \text{ or } H = 0.566 \sqrt[3]{Q \div r^2}$$

where

Q = capacity in gallons, D = inside diameter, H = depth of water in feet, and $r = D \div H$.

[1] See Turneaure and Russel, "Public Water Supplies," p. 711.

For a 100,000-gal. tank, with $r = \frac{1}{2}$, we have $H = 41$ ft. If we adopt this, and make $D = 21$ ft., then H would be 38.6 ft., leaving 1.4 ft. for variation in depth.

Walls.— From equation (1), using 14,000 lb. per sq. in. for the steel, and a depth of 40 ft.:

$$A_s = 62.5 \times 40 \times 10.5 \div 14{,}000 = 1.875 \text{ sq. in.}$$

From equation (3), using $f'_c = 150$ lb. per sq. in., and $n = 15$:

$$t = \frac{62.5 \times 40 \times 10.5 - (15 - 1)\ 150 \times 1.875}{12 \times 150} = 12.4 \text{ in.}$$

The tank walls will be made 12 in. thick throughout their entire height. This could be diminished in the upper portions, and in larger tanks it would doubtless be done, but this thickness is not excessive if carried to the full height of a tank of this size. The lower 4 ft. is widened out to 21 in. to give a base course for architectural effect.

Two rows of vertical bars will be used, as shown. Round ¾-in. rods will give a satisfactory spacing of about 5 in. at the bottom, and can be used throughout; ⅝-in. bars could be used, and would be easier to handle, but a slight saving in unit cost will result from using ¾-in. rods.[1]

The required spacing at any depth can next be computed from equation (2) which reduces to $d = 226 \div x$, giving the following:

At	elevation	0,	$x = 40$,	$s = 5.6$ in.
"	"	10,	$x = 30$,	$s = 7.5$ "
"	"	20,	$x = 20$,	$s = 11.3$ "
"	"	30,	$x = 10$,	$s = 22.6$ "

which is amply provided for in the design shown.

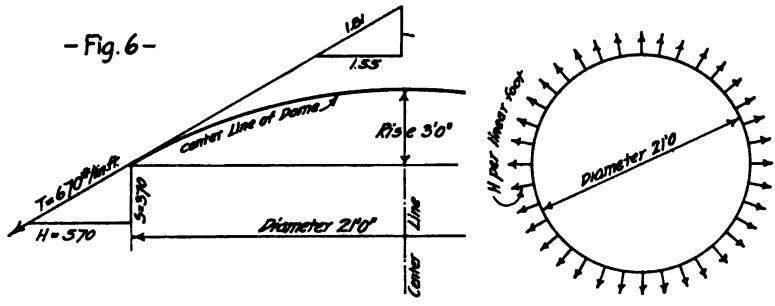
The cross-sectional area of the shell is 69 sq. ft., and 0.3 per cent. of this would be 30 sq. in., or about 150 ½-in. round rods should be used for vertical reinforcement. The average circumference of the tank is 70 ft.; hence by spacing these rods 12 in. centers, in two rows, as two rows of horizontal steel are used, about 140 rods would be required, and this would be considered satisfactory. It represents more vertical steel than is generally used, but this is considered advantageous, if it is well distributed.

Dome.[2]— This will be 21 ft. diameter, and a rise of 3 ft. will be

[1] Bars of ¾-in., either round or square, are known as "base," and a higher price per pound is charged for all bars smaller than this size.

[2] From article by L. J. Mensch, *Eng. Rec.*, June 1, 1912, p. 607. For circular domes of varying thickness, see SCHOOL OF MINES QUARTERLY, Vol. 19, Nov., 1897, p. 1.

assumed. A thickness of 4 in. will be found ample. The total weight will be approximately $w \pi d^2 \div 4$, or, taking w at 70 lb. (50 lb. dead load and 20 lb. live) $W = 24{,}250$ lb. The shear, S, per linear foot at the base of the dome will be this value divided by the circumference πd, or will equal $wd \div 4$, or 370 lb. per ft. This



shear or vertical reaction may be considered as the vertical component of a thrust T, as shown in Fig. 6, the horizontal component of which is H. Graphically we obtain $T = 670$ lb. and $H = 570$ lb. per lin. foot.

Hence the compressive stress on the base of the dome will be $T \div 12 \times$ thickness, or $670 \div 48$, or only 14 lb. per sq. in. The shearing stress will be $S \div 12 \times$ thickness, or $370 \div 48$, or 8 lb. per sq. in. These values are certainly safe. Also the component H produces ring tension, requiring some hooping metal at the base of the dome. The tensile stress in this reinforcement will be $H d \div 2$, or 6000 lb. One ¾-in. round bar would give $14{,}000 \times 0.442$, or 6200 lb., and would be sufficient to take care of this tension.

In order to stiffen the dome, prevent temperature cracks, and distribute any concentrated load that may come on it, ½-in. round rods will be used, 12-in. centers, in both directions. Either overflow holes just below, or a lantern type ventilator on top of the dome would ordinarily be used, but are not shown in Fig. 2.

Base Pressure.— The compression on the concrete of the wall at the base will be W, from above, plus the weight of the wall, plus the effect of wind load. The weight of the walls will be 150×40, or 6,000 lb. per lin. ft., which, combined with W, and divided by 12×21, gives about 25 lb. per sq. in. dead load. The total wind pressure, assuming 40 lb. per sq. ft., will be 24,500

lb., which gives a unit pressure on the base of $\pm$ 10 lb. from equation 4. The water pressure, assuming full upward hydrostatic pressure on the inside of the base joint and none at the outside, in lb. per sq. in. would be equal to 0.434 times the head in feet, or about 16 lb. on the inside, or average of 8 lb. The extreme variation in base pressure would therefore be from $25 - 10 - 8 = 7$ lb., to $25 + 10 = 35$ lb. per sq. in., which is entirely satisfactory.

THE PHYSIOLOGICAL CHARACTERISTICS OF ACETYLENE, WITH RESPECT TO ITS USE IN MINING.*

BY E. E. SMITH, PH.D., M.D.

Like every other step in the progress of civilization, the use of acetylene involves certain readjustments of previous notions. In the art of illumination, these problems of adjustment have been particularly definite and impelling. Thus, the pine knot did not give way to the candle, probably, without anxious consideration of the danger of spattering, soot making, and extinction by drafts. Many years of careful study were needed to solve the last of the dangers involved in the use of kerosene, while the difficulties connected with illuminating gas and electricity are still with us. This paper will be limited to the problems of adjustment presented by the use of acetylene as an illuminant.

This leads us at once to the inquiry, Is acetylene a direct poison? The answer is no. This question is asked with some seriousness, however, because, on the one hand, of the notoriously toxic action of common illuminating gas, due to the carbon monoxide which enters so largely into its composition, by reason of which the mind of the inquirer is already not only prepared to believe that acetylene is poisonous, but, in fact, in some instances has that idea rigidly implanted there. It is further asked with seriousness, because, in the literature of the subject, we find some views that it is poisonous. Early writers declared that it combined with the blood and had a marked poisonous effect, like carbon monoxide.

Any gas, when it replaces air, if incapable of supporting respiration, is injurious and even fatal, not because it is poisonous but because it deprives the body of oxygen. Because of this, acetylene is capable of doing injury. If it accumulate in some small, unventilated space, like the cabin of a boat, it is entirely capable of shutting off the supply of air, of preventing respiration and hence causing harm and even death. It suffocates because it is incapable of supplying oxygen, without which man cannot live.

* A paper read at a meeting of the International Acetylene Association, late in 1913, for a report of which the QUARTERLY is indebted to Secretary A. C. Morrison, 42d St., Building, New York.

When acting in this way, acetylene is not a direct poison; it does not do anything to the body to injure it. It does harm only indirectly, by withholding air. The recognition, then, of injury by suffocation throws no light on our inquiry whether it is a direct poison. The presence of common illuminating gas in air, even to the amount of a fraction of a percent., is distinctly injurious and may even be fatal, though such air contain an abundance of oxygen. The carbon monoxide contained in illuminating gas enters the blood through the lungs and attaches itself strongly to the coloring matter of the blood, rendering it incapable of taking up the oxygen of air though the air contain oxygen in ample amount. Thus death supervenes not because the body is denied oxygen but because, through the fixation of the coloring matter of the blood, it has lost its capacity to use oxygen. Has acetylene this or any other directly poisonous action? Some early observers said it had. They found fixation of haemoglobin quite similar to that of carbon monoxide and accordingly declared acetylene a poison. Moreover, it seemed to exercise the action of a direct poison on animals.

This was ascertained before acetylene was regularly produced from carbide. The acetylene of that date was made by the incomplete combustion of coal-gas, whence more or less carbon monoxide was present in the acetylene obtained, thus accounting for some degree of toxic action of the acetylene examined. Carbon monoxide is the poison of common illuminating gas.

With the discovery of carbide and its use for the production of acetylene, all of this has been changed. It is now found that acetylene from carbide does not contain carbon monoxide, that it does not have the property of fixing haemoglobin, and that it does not rob the blood of its capacity to take up oxygen from the air and carry it into the tissues. Hence the old allegation that acetylene is a poison because it deprives the blood of its oxygen-carrying capacity is no longer justified.

Another poisonous product sometimes present in the acetylene made by the old combustion process was hydrocyanic acid. Never in large quantities, it yet is so toxic that we can fully appreciate its effect. It is not present in the carbide acetylene and so may be dismissed from consideration. Another charge that is no longer justified is that acetylene is a poison because of the presence of

phosphine as an impurity. This forms when carbide is made from limestone containing phosphate, which is reduced by the action of the coke. The selection of limestone free from phosphate has practically obviated this impurity and any poisonous effect of the acetylene consequent thereto. Indeed, the present day product may be said to avoid the pitfalls of impurities so that its effect is determined by the characteristics of acetylene itself. We may consider then whether acetylene, as such, is or is not a direct poison.

My present observations have been directed to the inquiry whether it produced noticeable effect on human subjects when present in increasing amounts up to 2½ percent. during a period of 2½ hours. To this end, four men, including myself, were enclosed in a room of about 800 cu. ft. capacity; at the beginning and four times subsequently at intervals of a half-hour, acetylene was liberated in the room by throwing 450 grams of carbide into an open tub of water, this corresponding to the liberation of 4 cu. ft. of acetylene each time; that is, 20 cu. ft. in all, 2½ percent. of the capacity of the room.

To eliminate, as far as possible, the mental effect of the environment, the subjects were engaged in playing a game of cards. They were interrupted only long enough to take readings of their blood pressures, at half-hour intervals. The results of the experiment were quite negative. The game was continued throughout the period, excepting as noted. The blood pressure remained constant with one subject and was very slightly lowered from the inactivity with two, and absolutely no effect was noted that could be ascribed to any poisonous or other action of the acetylene. It was without effect.

This same result has been obtained in experiments on animals. In such amounts as used in the above experiments there is no effect. Indeed, acetylene may be increased up to 20 percent. and, if the mixture is so made as not to reduce the amount of oxygen, animals may be left in the atmosphere for some time, an hour or more, and will only become drowsy, from which they quickly recover when removed into ordinary air.

With very large quantities, or with 20 percent. admixtures acting for a longer time, the degree of drowsiness is increased. That is to say, the effect of acetylene in large doses is that of a narcotic, pro-

ducing loss of consciousness in proportion to its degree of action. When this action is pushed to a fatal termination, the final effect is upon the breathing center, inhibiting its action and so producing death.

It thus appears that carbide acetylene is not poisonous in the sense that common illuminating gas is, and that in large quantities, acting for some time, it produces a narcotic action. In respect to its toxicity, it presents no problem of adjustment under ordinary conditions. It, of course, may not replace in large degree the atmosphere we breathe, but otherwise no poisonous action need be anticipated.

A number of interesting problems are presented in connection with the use of the acetylene lamp as an illuminant in mines. I do not refer to those conditions where explosive gases are present, where protection from explosions is obtained through the use of the Davy lamp in some of its modifications, but to that large number of mines which are regularly illuminated by the naked flame. For this purpose, the miner's oil lamp has been used for many years. It is light in weight but its illuminating capacity is strikingly low and, moreover, is obtained at the expense of a smoking-out process that is amazing. It is a tribute to the miner's endurance that in the past he has accomplished so much under the conditions of poor illumination and soot-laden atmosphere which the use of the oil lamp has meant. The use of the miner's acetylene lamp affords an illumination that is wonderfully efficient and entirely soot free. Its use raises some questions that we may answer at this time. Before considering these, let us look at some of the problems which the miner has to face, upon which the choice of an illuminant may have some bearing. Of first importance is the composition of the air which he breathes.

For our present purpose, we may regard the atmospheric air as a mixture of 21 parts of oxygen and 79 parts of inert gas, mostly nitrogen. It is the oxygen that supports life. The proportion of oxygen may be diminished to a certain extent without noticeable effect, especially if the difference is made up by inert nitrogen. Under these conditions a reduction to 14 percent. produces little or no physiological effect. When the reduction reaches 12 percent., there is apt to be slightly deeper breathing, while 10 percent. is

an amount distinctly below what is physiologically advisable. Seven percent. may be regarded as the fatal point. It is an amount too small to support the life of animal or man for any considerable time. It must be kept in mind that these figures, 10 percent. the physiological insufficiency and 7 percent. the fatal point, are for oxygen with inert nitrogen, and without the admixture of poisonous gases.

There is always present in atmospheric air a small amount of carbon dioxide gas, commonly known as carbonic acid. This amount is very small, ordinarily not over 5 parts in 10,000. It is a product of the combustion of organic matter and is present in air exhaled from the body in breathing. As we shall see later, it is also a constituent of mine gases and so is of particular interest to us. I will call attention to what happens when it is added to the air.

To answer this question I have myself made direct observations. The apparatus employed was a closed cabinet, the inside measurements of which were approximately 67 x 30 x 69 in., having a capacity of 80 cu. ft. It was provided with a sliding door. Into the top a pipe entered and connected with three "sprays," one in each third of the top. Through this system gases were introduced. There was a small sample tube, easily movable, so that gas was withdrawn from any position desired within the cabinet, which was connected outside with (*a*) an exhaust bottle for withdrawing residual air from the tube; and (*b*) a gas-sampling tube. Collections were made over mercury and analysis was made over mercury in a Hempel apparatus. The cabinet was tightly built, but not sufficiently so to prevent escape of air sufficient to equalize the pressure without and within the cabinet when gas was introduced. A movable electric fan within the cabinet was adapted to produce motion of the air.

When carbon dioxide was mixed with atmospheric air, it was noted that such mixture produced an increased rate of respiration, even when the proportion of carbon dioxide was small. Rabbits and guinea-pigs showed a marked increase when as much as 4 to 5 percent. of carbon dioxide was present. With increasing proportions respirations became deep and labored, frequently, as was observed in guinea-pigs, reaching a condition of diaphragmatic spasm. Loss of muscular power developed so that, with guinea-

pigs, ability to support the body was lost when the carbon dioxide reached 20 to 25 percent. These symptoms developed irrespective of whether lamps were burnt in the same atmosphere. With rabbits, when lamps were burning, loss of muscular power appeared with the same proportion of carbon dioxide as with guinea-pigs, but in a single observation made without lamps, the loss of power appeared when the carbon dioxide had reached 36 percent. No effort was made to determine the percentage of carbon dioxide that would produce death, as it was believed that the proportion producing loss of muscular power represented the limit of possible tolerance. It may be noted, however, that in the experiment carried to 36 percent. carbon dioxide, the rabbit quickly recovered, two guinea-pigs recovered somewhat slowly, and one guinea-pig died, when the animals were removed into fresh air. Thus it appears that even with guinea-pigs, the fatal carbon dioxide proportion is not much if any below 36 percent., while the carbon dioxide warning point is not above 4 to 5 percent.

To test the effect of carbon dioxide on man, 10½ cu. ft. of carbon dioxide were passed into the cabinet, when a young man entered, the door being opened for that purpose and quickly closed. After entering, the fan was started. The rate of respiration at once rose from 18 to 48, being deeper and labored. He almost immediately complained of feeling dizzy. At the end of 2½ min. there was a feeling of impending loss of consciousness. A sample of the air mixture was at once taken and at the end of 3 min. the man came out. His respiration quickly returned to normal but his face was flushed and he complained for several hours of a slight frontal headache. Analysis of the sample showed 7 percent. of carbon dioxide. The experiment indicated that with man the warning point is reached below 7 percent. of carbon dioxide.

Such experiments lead to the following general conclusions regarding the physiological effects of increasing proportions of carbon dioxide. There is increase in the rate of breathing which, with 3 percent. dioxide, has become so marked that it gives unquestioned warning to the subject that some unusual condition of the air is rendering it unsuited for breathing. We may call this the physiological warning point for carbon dioxide. When the concentration reaches 8 to 10 percent., the breathing is not only rapid but

has become very labored, a condition termed dyspnea. Beyond 15 percent., further concentration, instead of increasing respirations, decreases them and the animal becomes narcotized, quite as though a substance like chloroform had been administered. At a concentration beyond 35 percent. the narcosis becomes fatal.

I have gone into the influence of oxygen decrease and of carbon dioxide increase on breathing and on life because these are conditions that may be presented by the air in mines. Moreover, the oil lamp has been relied upon to indicate to the miner whether or not the mine air is fit to breathe, air that sustains the flame being regarded as safe and air that extinguishes the flame as unsafe to breathe.

The disadvantages of the oil lamp are all too apparent. Its dingy light limits the working capacity of the miner, due to poor illumination. Aside from working capacity, the miner is not so well able to see the elements of danger presented by weakness in overhanging strata or structures. An even greater disadvantage is the production of soot by the flame. This both adds to the personal discomfort already great and also to the danger of dust explosions by addition of the soot to the dust-laden atmosphere. These conditions render an illuminant that is brilliant and soot-free a very great advantage. The acetylene lamp supplies such an illuminant in an admirable manner. In connection with its use it is desirable to determine its relation to composition of mine air, so that the miner may know in what way and to what extent it replaces the oil lamp as an index of safety. That is to say, we have here a problem of adjustment to which it is important to give a correct and definite answer.

First, then, let us consider the variations in composition that may be presented by mine air. Because of the limitations of access of outside air and especially because of the formation of gases in mines, mine air may present a considerable departure from the composition of outside air.

All ordinary foreign gases were known to the early miners as "damps," from the German *damf*, meaning vapor, the specific designation being indicated by an individual prefix. Thus, the gas characterized by its tendency to extinguish the flame was called black-damp, or, since it tends to produce suffocation, choke-damp;

the damp producing increased brilliancy of light, white-damp; that with a marked stink, stink-damp; that which readily took fire, fire-damp; the gas resulting from burning or explosion, after-damp, etc. These names were applied long before the composition of the respective gases was known. In consequence of the indefinite basis of the classification, an individual name was in many instances applied to mixtures that presented wide variation in composition.

Black-damp, on chemical analysis, has ordinarily proved to be a mixture of carbon dioxide and nitrogen, the proportion of carbon dioxide varying from very little up to 15 percent. or perhaps exceptionally 20 percent. As it is always mixed with more or less air, a corresponding amount of oxygen is present. Other gases, such as methane (fire-damp), carbon monoxide (white-damp), hydrogen-sulphide (stink-damp), also water vapor, may be present in greater or less amount.

We may well ask, then, what the name black-damp indicates. Does it mean carbon dioxide, which is the characteristic constituent; does it mean the carbon dioxide-nitrogen mixture; is it the carbon dioxide-nitrogen-air mixture; or is it the combination of any of these with other gases that are present in the mine air? Unfortunately, there has been no unanimity of usage in regard to this term, it having been used by different writers in almost every one of the above possible meanings.

If we were to establish anew the definition of the term, it would be doubtless wise to adopt a scientific meaning. As the matter stands, our meaning should be decided by priority, which is that black-damp is not simply carbon dioxide but rather a mixture of that with nitrogen in varying proportions, but we must not forget the different usages of individual authors.

Our problem is: How does the admixture of black-damp modify the respirability of mine air and how is this indicated by the oil and acteylene flames? It requires no facts other than those now before us to appreciate that it affects respirability in two ways. It diminishes the proportion of oxygen which, if reduced to 10 percent., would be unphysiological and to 7 percent., fatal; and it increases carbon dioxide which, when present to the amount of 3 to 4 percent., would produce marked increase in the rate of breathing.

As to when the change in composition, especially the carbon-di-

oxide increase, is indicated by the particular flames, has been the subject of personal experimental observations. The cabinet employed in the experiment previously described was used. In the earlier experiments with carbon dioxide, this gas was fed into the cabinet without previous admixture with air; in the later ones both air and carbon dioxide were fed into the cabinet through meters, entering the cabinet through a common tube. Thus they were well mixed and the rate of flow of each was regulated. Early experiments indicated that various factors influenced the extinction point, both for the oil and acetylene lamp. Let me relate what these factors were and how they exercised their influence.

A. Acetylene Gas Pressure.— From the outset it was observed that the pressure under which the acetylene gas was fed through the burner exercised a marked influence upon the extinction point. That is to say, with a series of lamps in which the acetylene gas pressure varied, as indicated by the character of the flame, it was not difficult, in a mixture of increasing proportion of carbon dioxide, to foretell the order in which the lamps would be extinguished, the lamps with higher acetylene pressure going out first. Indeed, it was frequently observed, where the escape of gas from the burner was under such slight pressure as not to give direction to the flame, that the extinction point would be very much higher than was observed with the ordinary burning flame. Care was therefore exercised to make our observations on lamps in which the gas production showed a normal amount of pressure.

B. Air Movement.— When there was no movement of air, excepting such as resulted from the convection currents produced by the lamps and by the introduction of the gas mixture, the extinction points were: for the acetylene lamps, 23 to 25 percent. carbon dioxide; for the oil lamps, 12 to 14 percent. carbon dioxide. With the production of a gentle movement of the air by fanning against the side of the cabinet, the extinction points were appreciably affected, being lowered in the case of the acetylene lamps to 22 to 17 percent. carbon dioxide; in the case of oil-lamps to 12 to 10 percent. carbon dioxide.

With the production of a strong movement of the air, by direct fanning of the lamps, in two experiments the acetylene lamps were extinguished when the air contained 9.4 percent. and 9.9 percent.

carbon dioxide, respectively, while the oil lamps were extinguished by the same breeze in atmospheric air.

The movement of the lamps worn on the heads of the miners would produce, in quiet air, the effects that result from a breeze with the lamps stationary. We may conclude, therefore, that in the case of the acetylene lamp the extinction point is lower than 25 percent., in proportion to the rapidity of motion; and with the oil-lamps, correspondingly lower than 14 percent.

C. Oxygen Proportion.— In the experiments mentioned, the oxygen was reduced only moderately by the admixture of the carbon dioxide in the form of pure gas. Undoubtedly, such reduction tends to lower the carbon dioxide extinction point. The effect, however, is only moderate, since the oxygen in all experiments was distinctly more than would sustain the flame if the specific effect of the carbon dioxide were neglected.

When the admixture of carbon dioxide is in the form of black-damp, however, the question of the oxygen proportion becomes an important factor for consideration. In these preliminary investigations, we were not able to study the effect of black-damp, since with the use of so large a cabinet, the quantity of nitrogen required would be much greater than it was practical to obtain.

D. Humidity.— In a number of experiments, water vapor was introduced into the gas mixture by blowing over the surface of water within the cabinet. In this way, the humidity was raised from approximately 35 to 65 or 80. Any effect upon flame extinction by carbon dioxide that may have resulted was within the limits of variation from the other factors considered. The conclusion is therefore reached that humidity affects the proportion of carbon dioxide required to produce flame extinction only within relatively narrow limits.

Comparing now the effects of carbon dioxide increase on flame extinction and respiration, we note that the first effect is a physiological one, when the proportion reaches 3 to 4 percent., there being an increase in the respiratory rate that is entirely adequate to warn persons of the atmospheric condition. Flame extinction occurs with oil at 13 percent. and acetylene at 26 percent. in still atmosphere, but at 10 percent. and 17 percent. with moderate motion. With either lamp the extinction point is too high above the physiological

warning point to make it of value to the miner. The conditions will have been recognized before the extinction point is reached. Should, however, the physiological warning be unheeded, flame extinction will occur, first with the oil and then with the acetylene flame, with either in ample time to prevent loss of life. The margin of safety, though greater with the oil-lamp, is adequate with the acetylene.

In considering the influence of oxygen decrease on flame extinction, I shall make use of observations made by Chester S. Heath, under experimental conditions different from those I have described.

He finds that with moderate motion an oil flame is extinguished when the oxygen is reduced to 16.5 percent.; in still air to 16.2 percent. With acetylene, at moderate motion, extinction occurred at 12.6 percent. and was dimmed in still air of the same composition, being extinguished in still air at 11.5 percent. It thus appears that the oil flame is extinguished with considerably less reduction of oxygen than the acetylene, but that the latter is extinguished before the reduction is fatal to man, which is at 7 percent. Moreover, in actual mining conditions, where the lamp is worn on the head, there will be sufficient motion; hence extinction will occur at a point somewhere above that observed with the experimental conditions.

Finally, it is not to be forgotten that the condition of extreme oxygen reduction without carbon dioxide increase, which was present in the experimental observations, is not encountered in actual mine air. The specific action of carbon dioxide admixture, that will be found in such conditions, will add its effect to the oxygen decrease and bring about the extinction of an acetylene flame at a point which is still further removed from unphysiological atmospheric conditions, and hence afford an increased margin of safety.

The miner, then, may conclude that a given admixture of blackdamp and air in the absence of other foreign gases will support life: (1) if it does not extinguish flame; (2) if it does not produce markedly increased respiration. Any atmosphere which does not give these warnings is respirable, though not necessarily desirable for continuous respiration. It does, however, give warning either physiological, or by the flame of acetylene as well as oil, that is adequate to prevent loss of life.

THE SWASTIKA GOLD AREA.*

BY EVEREND L. BRUCE.

The Swastika gold area centers about the town of Swastika at mileage 164 on the Temiskaming & Northern Ontario Ry. The section herein described comprises the southern half of the township of Teck and the northern half of the township of Otto. This area was first described by W. G. Wilson, who made a reconnaissance survey of the Blanche River for the Canadian Geological Survey, and later by L. L. Bolton, who accompanied Speight's survey party in 1904, and reported on the geology of the country from Round Lake to Abitibi, for the Ontario Bureau of Mines.

At the time of the gold rush to Larder Lake a number of claims were staked in the Swastika section and some work was done. The claims now held by the Lucky Cross Mining Co. and those of the Swastika Mining Co. were located at that time. In the depression which followed, operations were continued only on the latter group. The first development was done on the big quartz vein on the west side of Otto Lake, where a shaft was put down about 60 ft. and some drifting was done. Surface prospecting on the north side of the lake uncovered vein No. 1 which showed visible gold, and with the discovery of other veins near this one, work on the west side was abandoned, and a shaft was sunk and a five-stamp mill installed on the north side. This mill turned out several small gold bars before being dismantled in 1911, to make room for the present plant.

The discovery of gold in the Porcupine district led to renewed interest in the older section, and the summer of 1911 saw most of the old claims restaked and development work started on many properties.

The area lies just south of the Height of Land, and while the difference of elevation is seldom more than 200 ft., the country is rather rugged and broken. Rock outcrops are numerous and the areas of swamp are neither large nor continuous. The hills lie in roughly parallel east and west ridges, conforming with the strike of the formations. East of the Blanche River, however, the regularity is not so pronounced and the hills are more or less isolated.

* A Master of Arts thesis, Columbia University, 1913.

The Blanche River, which runs through this area, turns sharply east about a mile below Kenogami station and flows between two of these ridges until it breaks across the southern ridge in a series of rapids at Swastika. Just south of these rapids it is joined by Amikougami Creek, which forms the outlet of Amikougami Lake, north of Swastika, and flows in a fairly straight north and south course. Below the junction of the two streams is a broad valley in which the river meanders considerably before entering Otto Lake. Leaving the lake, the river again forms a series of rapids below which there is a long stretch of quiet water broken only where it crosses the syenite ridge in con. IV. In con. V the Blanche receives another tributary from the north, known as Murdock Creek. This stream, like Amikougami Creek, flows south in a fairly straight course. The lower part is shallow and rapid, but the upper reaches are sluggish. The Amikougami is broken by a few rapids, but forms a good canoe route to the lakes north of this district.

Petrology and Geology.

The prevailing rocks of the district may be grouped as follows:

Keewatin: — Greenstone; greenstone schist; carbonate rocks; intrusives.

Laurentian: — Augite syenite porphyry.

Huronian: — Conglomerate and greywacke.

Post-Huronian: — Feldspar porphyry; augite lamprophyre; Pleistocene and Recent.

Keewatin.— Greenstone and Schist.— The greater part of the Keewatin rocks are massive greenstones or their schistose derivatives. Where still massive, the greenstones show ellipsoidal weathering. This characteristic is pronounced in the rocks of the northeast corner of Otto. It also shows especially well on the hill to the east of mile-post 170, and on the face of the cliff near Kenogami station. Massive greenstones grade into rocks of schistose character. The schistosity becomes more pronounced near the contact with the later acidic intrusives, and the strike of the schists is usually parallel to the strike of the contact. The layers of schist are not at all regular; the rock often shows a columnar structure with twisted blocks the surfaces of which are serpentinized and highly polished. Rocks of this type outcrop along the railroad east

of Amikougami Creek. Between this stream and Murdock Creek, railroad cuttings show an anticlinal arrangement of the schists. At the western side they have a strike S.45°W., dip 70°N.W. The dip gradually becomes less steep until the schists are almost flat. It then increases towards the southeast and at a point two miles east of Swastika the strike is S.64°W., dip 80° southeast.

The greenstones and schist extend in a broad belt across con. IV and V Otto, and after crossing the Blanche River at Swastika, the northern boundary follows Amikougami Creek for some distance and then swings northeast across the southern part of Teck township.

A schistose greenstone east of Swastika consists entirely of actinolite needles together with sericite and magnetite. A rather more massive rock at the west end of Pike Lake has altered to chlorite, with a considerable quantity of carbonates, and contains fine particles of disseminated sulphides. In neither case is any trace left of the original structure or minerals. At mileage 162 on the T. & N. O. Ry., a cut goes through a very dense, black, basaltic looking rock which carries many small lenses of sulphides. Under the microscope it shows grains of quartz and a dark sooty material, suggesting a baked bituminous shale.

Carbonate Rocks.— Carbonates occur at several places in the area. Along the north side of Pike Lake, a narrow, more or less continuous, band of a much rusted carbonate rock separates the conglomerate from the grey feldspar porphyry. This band is so altered, and its character is so masked by the rusty weathering that it is impossible to determine its original character. In parts, the unweathered portion is light green in color, probably consisting largely of the chrome-bearing mica, fuchsite. Carbonate rocks also outcrop further west, in lot XII, con. VI, Otto. They are fractured, and the cracks are filled by quartz, producing a network of intersecting veinlets. Other small outcrops of carbonate rocks occur in the eastern part of Teck.

Serpentine.— The greenstones are often much serpentinized along slip planes and on the surfaces of the layers of schist. An outcrop of massive serpentine of small extent was observed on the Crawford claims, about two miles north of Swastika.

Iron Formation and Epidotic Rocks.— Banded iron formation,

consisting of alternate bands of magnetite and silica, occurs at several points along the southern edge of the Keewatin belt. A rock that seems to be related to it is exposed in the railway cuts in con. V, Otto. This rock consists of interbanded epidote and silica. Iron formation lies a short distance further south.

Keewatin Intrusives.— A large number of dykes of different varieties of rock cut the Keewatin greenstones. Some of these are so much altered as to suggest very early intrusions, and probably belong to the latter part of the Keewatin complex. Others are fresher, and may be of much later date. These are, however, relatively small in area and have been mapped as Keewatin, since their relationship to later rocks is not known.

Diabase dykes are very numerous in the greenstones. In most cases the rock is much altered, and most probably belongs to the Keewatin complex. Other dykes are fresh in appearance, and some of these may belong to the Post-Huronian series, but nowhere was an intrusion of diabase into conglomerates or greywackes observed. A considerable area of a massive igneous rock outcrops in con. V, lots 1 and 2 of Eby township. It is somewhat altered but still retains phenocrysts of a bronzy color. Farther north is a rock which evidently results from the metamorphism of an igneous rock of a porphyritic type. Some original minerals are still recognisable in a thin section, and the original structure is not much affected. Feldspar phenocrysts are present, and can be determined as near albite in composition. A few shreds of green hornblende are left but most of this mineral, which apparently formed the largest number of phenocrysts, has changed to chlorite. Sericite is also abundant, due to the alteration of the feldspathic constituents.

Intruding the greenstones near Otto Lake, and again on the eastern side of Murdock Creek, is a grey feldspar porphyry which has been included in the Keewatin series. The feldspar phenocrysts appear distinctly on the surface. Under the microscope the rock is distinctly porphyritic. The phenocrysts are plagioclase feldspar, approaching albite, set in a ground mass of quartz, feldspar, and hornblende. Considerable alteration has taken place, producing chlorite, sericite, kaolin, carbonates, and epidote. Magnetite and chalcopyrite are present. The phenocrysts make up a large part of the rock, the areas of ground mass being narrow.

The analysis of this rock gives: SiO_2, 60.71; Al_2O_3, 14.87; Fe_2O_3, 3.26; FeO, 3.60; MgO, 3.52; CaO, 3.29; K_2O, 2.52; Na_2O, 4.40; CO_2, 1.68; H_2O, 2.35 percent. This calculates to a norm consisting of: Quartz, 17.34; orthoclose, 11.10; albite, 37.16; anorthite, 1.67; magnetite, 1.20; chlorite, 12.93; kaolin, 4.82; sericite, 3.14; hornblende, 7.70 percent. This indicates the acidic nature of the feldspar. The large amount of chlorite present explains the rather high percentage of water in the analysis.

Other sections examined show almost complete alteration of hornblende to aggregates of chlorite and epidote. A thin section of the rock in the railway cut near the water tank at Swastika shows an abnormal facies of this formation. Here the ferro-magnesian minerals are altogether lacking, the whole rock consisting of albite, quartz, and alteration products such as carbonates, sericite, chlorite, epidote, and magnetite. The ordinary type is a quartz-diorite porphyry; the abnormal type approaches a quartz keratophyre.

Crossing the eastern boundary of Teck is an outcrop of porphyritic hornblendite. It is roughly elliptical in outline and is entirely surrounded by drift, hiding the contact with the Keewatin rock around it. Near the center of the exposure the hornblende crystals are large, often being an inch in diameter, and the whole rock consists of dark minerals. Towards the margin it becomes finer grained, and more light colored constituents appear. The rock is composed of phenocrysts of green hornblende and brown biotite, with a little magnetite, apatite, and titanite. Inclusions of light green pyroxene, variety diopside, occur in the hornblende crystals. Very little alteration has occurred and the hornblende is undoubtedly primary. The small amount of secondary material present is epidote, apparently from feldspar. The unaltered character of the rock suggests that it may be much later than the Keewatin series, possibly a basic segregation from one of the acidic intrusives.

Many other smaller dykes cut the Keewatin rocks at different places in the area. Basaltic dykes from an inch up to 60 ft. wide show in the railroad cuts east of Swastika. In one of these cuts a dyke of andesite porphyry 6 ft. wide intrudes the serpentinised greenstones, it has a very striking porphyritic structure, the phenocrysts being feldspar and hornblende. The feldspars are well bounded, tabular crystals of albite showing zonal structure; the

hornblende is of the ordinary green variety, occurring in prismatic, much elongated crystals. Cross-sections of these show diamond shaped or hexagonal outlines, and some of the crystals show distinct zonal growth, an uncommon feature in hornblende. Fragments of biotite occur, now light green in color from alteration, and, in some places, completely altered to chlorite and magnetite. Apatite is also present.

A dyke of similar rock, but more altered, occurs on the Reeves claims, north of Pike Lake. This dyke is cut by a narrow mica lamprophyre consisting almost entirely of greenish biotite, with a little magnetite.

Laurentian.— All those relatively fresh, acidic rocks of the area, the relationship of which to the conglomerate is not known, are included in the Laurentian series. In the northwest part of the district, conglomerates were found overlying acidic igneous rocks, although not directly in contact, and containing pebbles very similar to the underlying formation. In other places no relationship was observed. The character of the feldspar, and the presence of augite in the syenite classed as Laurentian, suggest that it may be one member of a series of differentiation products of a parent magma, of which red feldspar porphyry and augite lamprophyre, to be described later, are other facies. In the absence of any observed field relationship, however, it has been mapped as Laurentian.

There are three areas of such rocks in the district. The largest forms a prominent ridge lying between con. IV and V, Otto, and extending east and west. A boss-like mass intrudes Keewatin rocks north of the railroad, with its center in H. R. 737. The third is a small exposure south of Perron Lake, in the northwest part of the sheet.

The contact of the first of these with the Keewatin can be seen in the western part of the township, forming a broad zone. Towards the center and east, however, the Laurentian ridge is separated from Keewatin rocks by a wide drift-filled valley. The rock consists largely of feldspar and is often very coarse grained, the feldspar reaching a diameter of an inch or more. The coarse-grained rock is cut by finer-grained stringers of the same composition. These withstand weathering rather better and stand out from the surface; the easy cleavage of the feldspars causes the coarse rock to break

down easily. In thin section, the rock exhibits a tendency towards porphyritic structure. It consists of feldspar, augite, biotite, hornblende, magnetite, zircon, apatite, and titanite. Quartz is present in the small areas of ground-mass that separate the feldspar phenocrysts, but is not very abundant. Chlorite, epidote, and secondary hornblende occur as alteration products. The augite is the oldest of the more important constituents, occurring as well formed crystals and sometimes as inclusions in the feldspar. The pyroxene is often fringed with uralite. The most striking characteristic of the rock sections is the structure of the feldspar. It has a peculiar, ragged, almost brecciated, appearance which seems to be due to a crude microperthitic intergrowth. An analysis of the finer-grained part of this rock gives the following composition: SiO_2, 61.65; Al_2O_3, 18.91; Fe_2O_3, 2.37; FeO, 1.48; MgO, 1.11; CaO, 2.10; K_2O, 4.20; Na_2O, 5.59; H_2O, 0.60 percent. The corresponding norm is: Quartz, 6.30; orthoclase, 18.72; albite, 47.20; anorthite, 5.50; magnetite, 1.70; chlorite, 2.50; biotite, 10.05; hornblende and pyroxene, 6.23 percent. The rock is essentially an augite syenite porphyry.

The second Laurentian area consists of syenitic rocks of a very similar character, but the feldspars do not attain so large a size. The rock of the third area is not so coarse in grain as that of either of the others and shows a more distinctly porphyritic texture.

Huronian.— Huronian rocks occupy the western part of the township of Teck, from the boundary line northward to the limits of the sheet, and eastward as far as Swastika. Northeastward from Swastika the contact with the Keewatin is along the course of Amikougami Creek; it then swings eastward again. The Huronian forms a rather high area, rising gently to the north for a mile and a half from the Blanche River, and then breaking into a series of east and west ridges.

For the most part the series consists of conglomerate and greywacke. These are fresh and unsqueezed, away from the contact, but along the borders of the formation the rock is a slate standing at a high angle and much rusted and altered. At a short distance from the contact, the conglomerate and greywacke are quite fresh in appearance. It may be possible that the highly tilted slates represent a series older than the fresher conglomerate, or the relation of the Huronian and the Keewatin may be that of a faulty contact.

The conglomerate is massive and shows no bedding. It varies considerably, even within short distances, being crowded with pebbles at one spot, while a few feet away pebbles are so rare that only careful search will reveal them. Most of the pebbles are well rounded, evidently water-worn fragments of feldspar porphyry, very similar to the grey feldspar porphyry previously described. Reddish, felsitic pebbles also occur, and a few pieces of granite were found. Greenstone pebbles are common, and fragments of smooth serpentinized rock like that east of Swastika also occur. The most striking constituents of the conglomerate, although less in number than the others, are pebbles of jasper, varying from the size of a pin-head or less up to a diameter of four or five inches.

Where pebbles fail, the rock passes into a typical massive greywacke. Near the western boundary of Teck the typical greywacke grades into a reddish rock of an arkose type. Thin sections of a typical variety show fragments of rock most of which are porphyry, with feldspar or green hornblende phenocrysts. Along with these are fragments of minerals, albite, quartz, hornblende, and magnetite, set in a matrix of finer material of the same kind. Secondary minerals, chlorite, sericite, and kaolin are present.

Post-Huronian Intrusives.— At least two igneous intrusives are later than the sedimentary rocks. These are of distinct types and their relation to each other is not known. Both occur as dykes cutting the greywacke and conglomerate, and sometimes as masses of considerable area.

One of these is a light reddish rock with a tendency to develop feldspar phenocrysts. A small knob of this rock is encountered in the first railway cut west of Swastika. It extends but a short distance south of the railway and sends off a tongue along the base of the hill of conglomerate that rises south of the right of way. The conglomerate along the contact is considerably altered and the pebbles are squeezed and drawn out. East of Amikougami Creek is another small exposure of similar rock, and on the Costello claims a small exposure of greywacke is cut by at least three different dykes of this rock. Many other small dykes of this rock occur at different places in the conglomerate.

A specimen from the cut west of the station shows under the microscope a granitoid texture, and consists almost entirely of an

acidic plagioclase feldspar with considerable amounts of secondary products. Dolomite is the chief of these, occurring in small rhombohedrons massed together, or in veinlets through the feldspar; it seems to have been introduced rather than to be a product of alteration of the rock minerals. Aggregates of epidote and other secondary minerals are present, and a little chalcopyrite is scattered through the section.

The analysis of this rock is as follows: SiO_2, 56.25; Al_2O_3, 18.42; Fe_2O_3, 1.56; FeO, 2.41; MgO, 2.38; CaO, 6.13; K_2O, 0.32; Na_2O, 8.10; CO_2, 4.58; H_2O, 0.22; S, 0.10 percent. The corresponding norm is: Quartz, 0.66; orthoclase, 1.70; albite, 68.20; anorthite, 12.23; magnetite, 1.20; chlorite, 1.70; kaolin, 0.30; hornblende, 4.62; pyrite, 0.30; dolomite, 9.63 percent.

This shows over 80 percent. of feldspar. The small amount of orthoclase probably unites with some of the soda to form anorthoclase. Hornblende does not occur in the sections examined, and that shown in the norm represents minerals such as epidote, chlorite, and other secondary products.

The other Post-Huronian intrusive is basic in character, variety augite lamprophyre. It is black, and weathers with a pitted surface; on a fresh fracture it sometimes has a faint purple shade. Parts of the rock show aggregates of secondary minerals which give it the appearance of having amygdaloidal structure. This general character suggests rock of the Keewatin complex, but on a small point on the south shore of Elsie Lake, near the west end, a narrow dyke of this rock, striking northeast, cuts the greywacke. Other dykes of the same rock occur at points on the trail north to this lake, and some of these include fragments of Huronian in them.

On the north bank of the Blanche River, in Eby township, augite lamprophyre forms the face of the high bluff for some distance. The contact is on the top of the ridge, and near it the lamprophyre is brecciated and recemented by the same kind of rock. Thin sections show numerous phenocrysts of augite set in a groundmass made up of needle-like feldspars and smaller augite crystals. Magnetite is scattered throughout in considerable quantity, and apatite is noted both as inclusives in the phenocrysts and in the groundmass. Chlorite and epidote occur as alteration products. The

augite is green in color and occurs in well formed, blocky crystals. The feldspars are too small to be determined optically. The apparently amygdaloidal portions above mentioned are areas of secondary minerals, but they seem to be replacements of certain parts of the rock rather than fillings of vesicular spaces. The analysis of this type is as follows: SiO_2, 52.29; Al_2O_3, 19.38; Fe_2O_3, 4.40; FeO, 6.00; MgO, 3.54; CaO, 7.79; K_2O, 4.12; Na_2O, 2.12; H_2O, 0.95 percent. The corresponding norm is: Orthoclase, 24.00; albite, 17.86; anorthite, 28.07; magnetite, 2.80; chlorite, 5.05; kaolin, 2.99; pyroxene, 19.55 percent. Since the variety of feldspar could not be determined, the relation of augite to anorthite, as calculated, may not represent the true proportions of the rock.

Pleistocene and Recent.— The Pleistocene is represented only by unsorted sands and gravels, and these do not occur in any great development in the area. Since Pleistocene time the streams have formed alluvial plains in favorable places along their valleys. The largest of these is along the Blanche River in con. V, Otto. In the swampy and marshy areas between the rock exposures, peat has formed to some depth. South of the section, towards Round Lake, the Pleistocene and recent deposits are much more important formations.

Gold-Bearing Veins.

Visible gold occurs in quartz veins in at least two parts of the district. One lies near Otto Lake, and includes the Swastika mine and the Reeves claim. The other lies east of Amikougami Creek on the Lucky Cross Mining Company's claims.

The veins are of the common lenticular type, with steep dips, as a rule. The quartz is the white crystalline variety with dark streaks in it. A slight fracturing followed the first quartz deposition, and tiny veinlets of a more transparent variety cut across the older quartz, like water lines on paper. Sulphides occur in the veins, as chalcopyrite and pyrite. The gold is very often associated with the sulphides, or with the dark lines in the quartz, but occasionally is found alone. On the Swastika claims the veins cut greenstone and grey feldspar porphyry. On the Reeves and neighboring claims the wall rock is feldspar porphyry and the rusty carbonate rock. The relationship in the Lucky Cross veins is similar to that in the

Swastika. The porphyry is in small dykes, forming sometimes one wall, sometimes, for a short distance, both walls of the vein, which does not seem to vary with change of country rock.

Veins of similar physical characteristics are found in the conglomerate and greywacke but, so far as known, no gold has been found in them. It is possible that they are of different age than the veins found in the Keewatin rocks, or, if of the same age, the Keewatin may have favored precipitation of gold. If the latter explanation is correct, it seems likely that the fracturing of the rock and the deposition of vein material and gold are due to the Post-Huronian intrusive rocks, and probably more particularly to the acidic type than to the augite lamprophyre.

Mining Development.

The Swastika Mining Company has done most of its development work on three veins on the north side of Otto Lake. The largest of these is 8 to 9 ft. wide, striking north and south. This is intersected by two other veins, the smaller having 8 to 9 in. of quartz. Most of the ore already stoped has come from the large vein above the 35-ft. level. The mine now has a three-compartment shaft down 200 ft., the old shaft being used merely for ventilation. Considerable drifting has been done. A new equipment has been installed, consisting of two 125-h.p. Jenckes boilers, a 10 x 12 in. double-drum hoist, and a 12-drill Sullivan compressor.

On the Reeves claims, north of Pike Lake, two veins 8 and 9 ft. wide have been stripped for 100 ft. or more. These veins strike N.E. and S.W., and are about 50 ft. apart. In the larger of the two, visible gold occurs at its junction with a small quartz vein.

On the Lucky Cross claims, visible gold was found first in a small vein that shows in the railway cut just east of Amikougami Creek. North of the right of way, this vein is about 8 in. wide and carries visible gold in a band crossing the vein at an angle from wall to wall. Later prospecting has uncovered other veins north of this, one of which has a width of 12 ft. A plant including a six-drill compressor has been installed.

The Homestead Mining Company has a vein in the rusty carbonate rock near the Huronian contact, on which they are driving an adit into the hill.

The observations on the area were made under the general supervision of Mr. A. G. Burrows, who spent a few days in the field. Valuable advice and assistance in the petrographic determinations were received from Prof. C. P. Berkey, while the data were being worked up in the Departments of Geology and Mineralogy at Columbia University.

BOOK REVIEWS.

Mine Surveying. By Edward B. Durham, Associate Professor of Mining, University of California. Limp leather; 5 x 7½ in.; 391 pp.; 211 figs. McGraw-Hill Book Co., New York. 1913. Price $3.50.

This book is about the best that has appeared on the subject, but its utility for either students or engineers is diminished, first, by its disjointed manner of presentation, and second by the inclusion of many trivial remarks, which are always irritating to anyone with a modicum of ordinary gumption. Under this last condemnation would come such statements as: (p. 46) a transit must be so set as to allow space for moving around it, and the points to be sighted must both be visible from the instrument; or (p. 236) nails driven into a guide as markers for taping the depth of a shaft must be so placed as not to be struck by the shoe of the cage. Many like citations could be made. This is a common failing in all attempts to make a weighty treatise out of a relatively simple matter.

The lack of sequence, first noted, is a serious defect in a students' textbook; an engineer would not find this so detrimental if only he could procure all the desired information on a given question within the bounds of a single chapter. This is not possible in the present work. Thus, methods for supporting a shaft-plumbing wire are described partly in Chap. XI, and partly in Chap. XII; methods for making set-ups at difficult stations, with trivets and brackets, are described in the chapter on steep sights, to which they have only a casual connection, and should have been included in the chapter on the general subject of transit traversing. There is no reason why the chapter on shaft plumbing should be set apart, and follow chapters on computations, mapping, mining problems, and miscellaneous appliances, as though this operation were only distantly related to the general process of underground surveying. In short, a large proportion of the material in the book is misplaced, and if it were not for a fairly good index, the tangle would be impenetrable.

The most valuable chapters of the book are those on "Special Problems in Mine Surveying," in which several commonly occurring problems are solved by the application of the coordinate principles; "Steep Transit Sights," which describes the several devices for accomplishing this operation; "Tunnel Surveys," which describes the methods and appliances actually used in a number of prominent engineering feats; "Mine Models," describing the several methods of construction; and "Magnetic Surveys," which discusses the principles involved, and describes the implements and methods used in prospecting for magnetic ore deposits.

Throughout the book, the author quotes freely from literature on the subject. The citations are often very valuable, as, for example, the methods of shaft plumbing in connection with some recent engineering work in New York City; but in other instances, certain methods described, to which the author lends dignity by quoting, do not deserve this distinction, and should have been allowed to repose in obscurity. It

was hardly necessary, either, to extract from their museum cases a variety of obsolete compasses, theodolites, and water-levels. This criticism is not directed at the German hanging compass, which still has a legitimate field of usefulness. The three-tripod method has many points of excellence under rare conditions, but for general work it scarcely deserves the emphasis placed upon it by the author.

The volume is neatly and conveniently bound in pocket-book size, being in pleasing contrast with a previous volume on the same subject issued by the same publishers. Type and illustrations are excellent, and the text is remarkably free from defects; we note only a typographical error in the table of contents, and a cut upside-down on page 111. The maps are particularly good, and denote the expenditure of a great amount of time and care in their preparation. E. K. J.

Outlines of Mineralogy for Geological Students. By Grenville A. J. Cole, Professor of Geology in the Royal College of Science for Ireland. Cloth; 4½ x 7 in.; viii + 340 pp.; 124 diagrams. Longmans, Green & Co., New York. 1913. Price $1.60 net.

This book is a discussion of the common minerals by a geologist, who gives particular attention to their appearance in rocks and "as constituents of the earth and influencing its features." The descriptions of species, while somewhat meagre in details as to characters, are often made very interesting by discussions of genetic relations, mode of occurrence and alterations. Every mineralogist will read with pleasure the pages on dolomite, calcite, aragonite, quartz, water and kaolin.

The descriptions of "mineral characters" and the methods and apparatus described are not such as would usually suit for class work. They do not seem to guide definitely to practical results. For instance the original Wollaston goniometer, Walker's specific gravity balance, and even the modern Herbert Smith refractometer do not enter much into ordinary mineral testing. In the summary of "the essential features of the seven crystal systems" there is a praiseworthy attempt to break away from the elaborate study of unnecessary detail, but it is not stated how these features may be recognized directly in the real crystal. The student is held to the model or drawing, but told that "the skilled crystallographer reads off this symmetry from the way his angular measurements repeat."

To sum up, the book is interesting, but for class work is unbalanced. It contains many facts that the teacher of mineralogy will gladly add to his notes, and it lacks many others that will be needed in any course in mineralogy. It is designed, as stated, primarily "for those who are interested in geology and are thus in need of an introduction to the larger works of reference." A. J. M.

UNIVERSITY NOTES.

Civil Engineering Society.— The first of a series of meetings which has been arranged for the Winter and Spring was held on the evening of Nov. 18, 1913. Mr. Robert Ridgeway, chief engineer of subway construction of the Public Service Commission gave a very interesting lantern-slide talk on the construction of the dual subway system.

The Society has undertaken a new activity, that of visiting various construction works about the city. Through the courtesy of Mr. Ridgeway, the first of these inspection trips was held on Nov. 28, to the subway construction work at the lower end of the Borough of Manhattan.

The Secretary, Mr. Wm. W. Havens, 469 East 134th St., New York, would be pleased to notify alumni members of the society of the forthcoming meetings if they will express to him their desire for such notification.

Highway Engineering.— The non-resident lecturers in the graduate course in highway engineering at Columbia University appointed for the 1913–1914 session are as follows: John A. Bensel, New York State Engineer; William H. Connell, Chief, Bureau of Highways and Street Cleaning, Philadelphia; C. A. Crane, Secretary, The General Contractors' Association; W. W. Crosby, Chief Engineer, Maryland Geological and Economic Survey; Charles Henry Davis, President, National Highways Association; John H. Delaney, Commissioner, New York State Department of Efficiency and Economy; A. W. Dow, Chemical and Consulting Paving Engineer; H. W. Durham, Chief Engineer of Highways, Borough of Manhattan; C. N. Forrest, Chief Chemist, New York Testing Laboratory; Walter H. Fulweiler, Chief Chemist, United Gas Improvement Co.; Frank B. Gilbreth, Consulting Engineer; George P. Hemstreet, Superintendent, The Hastings Pavement Co.; Samuel Hill, President, American Road Builders' Association; D. L. Hough, President, The United Engineering and Contracting Co.; J. W. Howard, Consulting Engineer; Arthur N. Johnson, State Highway Engineer of Illinois; William H. Kershaw, Manager, Paving and Roads Division, The Texas Company; Nelson P. Lewis, Chief Engineer, Board of Estimate and Apportionment, New York City; Harold Parker, First Vice President, Hassam Paving Co.; Paul D. Sargent, Chief Engineer, Maine State Highway Commission; Philip P. Sharples, Chief Chemist, Barrett Manufacturing Co.; Francis P. Smith, Chemical and Consulting Paving Engineer; Albert Sommer, Consulting Chemist; George W. Tillson, Consulting Engineer to the President of the Borough of Brooklyn.

During December, 1913, January and February, 1914, the following addresses were delivered by outside lecturers:

Dec. 13, Arthur N. Johnson, "Economics of Highway Engineering in the Middle West."

Dec. 15, Samuel Hill, "Highways of the Northwest."

Dec. 23, Walter H. Fulweiler, "Manufacture of Refined Water-Gas Tar."

Dec. 27, Philip P. Sharples, "Manufacture of Refined Coal Tar."

Jan. 9, William H. Kershaw, "Mining, Transportation and Storage of Asphaltic Oils."

Jan. 15, William H. Connell, "Organization and Methods of Street Cleaning Departments."

Jan. 20, Paul D. Sargent, "Gravel, and its Use in Highway Construction."

Jan. 23, George W. Tillson, "Details of Construction of Car Tracks in City Pavements."

Jan. 24, J. W. Howard, "European Rock Asphalts, Mining, Preparing, and Using."

Jan. 29, Francis P. Smith, "Plant, Highway, and Laboratory Inspection of Bituminous Materials."

Feb. 5, Harold Parker, "Responsibility of Contractors for Construction of Roads and Pavements Designed by Engineers."

Feb. 9, H. W. Durham, "The Highways of Panama."

Feb. 17, George P. Hemstreet, "The Manufacture of Asphalt Blocks."

Mechanical Engineering Society.— Nov. 7, 1913.— After an introductory speech by Pres. Schmidt, outlining the objects and aims of the society, Mr. Barnaby, '15, interested the audience with descriptions of the various types of aeroplanes, and the value of experimenting with models under conditions similar to those met with by the man-carrying machine. He also explained the greater relative stability of the model over the man-carrying machine. Mr. Barnaby said that he had always met with best results with models having the elevating plane in front of the main plane, and thought there was chance for greatest development in the large machines along these lines.

Dec. 5, 1913.— The speaker of the evening was Mr. W. T. Price, Oil Engine Sales Manager for the De La Vergne Machine Co. He gave an interesting lecture on the "Development of the Oil Engine in the United States."

Mr. Price followed the development of the gas engine into various fields of industry, outlining its development to the present date. He also showed the limitations in the building of large engines after the designs of successful small ones, citing as an example the Hornsby-Akroyd type, which, while quite successful up to 125 h.p., gave way before other designs for large engines. The first large gas engines were used as blowers for blast furnaces, but now there are many small plants operating upon gas and oil engines. Mr. Price closed his lecture by figures comparing the cost of power obtained from the oil engine, with purchased electric power. The figures showed that, in spite of the increasing cost of oil, it is much better economy to use the oil engine for power if the installation is to be a permanent one. After two years, the saving in the cost of oil over electric power entirely balances the first cost of the engine. The lecture was illustrated by lantern slides, showing various types of engines and installations.

Jan. 9, 1914.— The speaker, Mr. H. L. Gantt, was introduced by Pres. Schmidt. His topic was, "The Relation of Employer to Employee."

Mr. Gantt said that the college graduate encounters a different class of people from those he has been accustomed to. He finds the workman

doesn't know the things he does, and is apt to think him ignorant. He doesn't know the things that the workman does, and the workman calls the graduate ignorant. The real problem to face is human nature, how to deal with men. No class of men is more susceptible to proper treatment, nor more resentful of improper treatment, than workmen. Mr. Gantt pointed out the fallacy of low wages, for a man who is paid as little as possible will deliver as little as possible, just enough to hold his job. When an employee feels that he isn't getting his share, antagonism is aroused. The best results are accomplished when there is a spirit of cooperation between the employer and the workman, and the way to obtain this is to set a task for the men, then show them how to do it, and pay them well. It has been demonstrated that, on an average, a trained man will do about three times as much as an untrained one. By showing them how to do the work, and paying them properly, production goes up and the wages cost goes down. Mr. Gantt showed charts illustrating these facts.

Sigma Xi.— The first meeting of the year was held on the evening of Nov. 25, 1913, and was addressed by Joseph Barrell, Professor of Geology at Yale University, on the subject: "Some Physical Conditions which have Guided Evolution."

On Dec. 12, Henry F. Hornbostel, '91, consulting architect, formerly an official of the City of New York, gave an illustrated lecture on "Architectural Treatment of Engineering Structures," concluding with well expressed views on architectural education.

On Feb. 6, 1914, Dr. Arthur L. Day, Director of the Geophysical Laboratory, Washington, D. C., delivered an illustrated lecture on "Observations on the Gaseous Emanations from Volcanoes."

Forthcoming meetings will be as follows: Mar. 6, annual meeting for the election of members. Mar. 24, Dr. Henry N. Russell, Professor of Astronomy at Princeton, will speak on "Eclipsing Variable Stars." April 17, annual initiation of new members, followed by a banquet. May 8, Arthur G. Webster, Professor of Physics, Clark University, will deliver an illustrated lecture on "Sound and its Measurement"; at this meeting, the Columbia chapter of Phi Beta Kappa will be the guests of Sigma Xi.

Phi Lambda Upsilon had an open meeting on Dec. 18, 1913, at which Dr. P. A. Levene, Ph.D., M.D., director of the chemical laboratory of the Rockefeller Institute for Medical Research, delivered a lecture on "The Mechanism of Biological Utilization of Sugars."

On the evening of Jan. 9, 1914, the society partook of an informal dinner at the Chemists' Club, and attended the American Chemical Society's meeting at which Dr. Mees, of Rochester, N. Y., spoke on "Methods of Photographic Research."

On Feb. 5, Mr. H. E. Howe, director of the chemical laboratory of the Bausch & Lomb Optical Co., Rochester, N. Y., spoke on "The Manufacture of Scientific Glass."

FACULTY NOTES.

Professor Charles E. Lucke, head of the Department of Mechanical Engineering, has been asked by the International Engineering Congress, through its Committee on Papers, to prepare for the joint meeting in 1915 one of the papers on The Internal Combustion Engine. In their request the Committee makes the following statement: "The Committee feels that there is no person in the country who can better give a review of the status of the internal combustion engine than yourself, and trusts that you will accept the invitation extended."

Arthur H. Blanchard, Professor in charge of the Graduate Course in Highway Engineering, on Dec. 6, 1913, delivered an illustrated lecture on "Modern Developments in Highway Engineering" before the Drexel Institute of Philadelphia.

ALUMNI NOTES.

1878. Richard A. Parker has been elected President of the Colorado Scientific Society for the year 1914.

1885. Joseph Struthers, E.M., Ph.D., has been re-elected Treasurer of the United Engineering Society, 29 West 39th St., and also Secretary of the Engineers' Club, of New York City.

1885. Richard Moldenke, E.M., Ph.D., has recently been abroad in the interest of international specifications for pig iron, pipe, and other castings. These specifications are intended to facilitate international trade only, and are now under consideration for adoption by all the iron producing countries of the world. The work is under the auspices of the International Association for Testing Materials.

1889. Herbert P. Whitlock, C.E., connected with the New York State Museum, at Albany, was elected a Fellow of the American Academy of Arts and Sciences, in January.

1895. C. S. Herzig, E.M., announces the removal of his office from Salisbury House to 1 London Wall, London, E.C.

1896. R. S. McCaffery, E.M., recently Professor of Metallurgy at the University of Idaho, has been appointed to a similar position in the University of Wisconsin, Madison, Wis., and began his duties in February.

1897. Newton B. Knox, E.M., of Bewick, Moreing & Co., London, has recently returned from Columbia. He delivered an exceedingly valuable lecture on hydraulic and dredge placer mining, in all its aspects, before the students of mining in Columbia, on Feb. 17.

1898. Alexander P. Rogers, C.E., Ph.B., was recently elected to membership in the Mining and Metallurgical Society of America.

1899. John D. Irving, Professor of Geology at Sheffield Scientific School, has recently returned from Leadville, Col., where he has been putting the finishing touches on his report for the U. S. Geological Survey, a work which was begun under S. F. Emmons 15 years ago.

1902. R. H. Cromwell, E.M., of the Tezuitlan Copper Co., returned to New York in January, to be with the head office of the company, at 82 Beaver St.

1903. Julian C. Smallwood, Mech.E., Associate Professor of Experimental Engineering, Syracuse University, is the author of a new book on "Mechanical Laboratory Methods."

1903. Earl R. Pembroke, E.M., announces the opening of his consulting office at 24 East Broadway, Salt Lake City, Utah. He has been engaged in different enterprises throughout the Western country since graduation, and the QUARTERLY wishes him success in his new undertaking.

1903. S. F. Shaw, E.M., since the practical cessation of work at the A. S. & R. mines in Mexico, has been engaged in experimental work at the Horn Silver mine, Frisco, Utah, where W. H. Hendrickson, '03, is superintendent.

1904. A. H. Beyer, C.E., is chief engineer for Alexander Potter, Consulting Engineer, 50 Church St., New York. He has prepared designs for a number of water-supply and sewerage projects in the last few years, which involve many new, interesting, and entirely successful applications of reinforced concrete. Articles on some of these designs will be found in *Pro.* American Water Works Assoc., 1912, p. 89, *Eng. Record,* Nov. 29, 1913, p. 616, *Journal* New England Water Works Assoc., June, 1912, p. 138.

1904. George A. Sherron, E.M., is now City Engineer and Commissioner of Highways for Norwalk, Conn.

1904. Leonard J. Lewinson, E.E., has been appointed engineer of lamp tests by the Electrical Testing Laboratories, with which he has been connected for the past nine years.

1904. J. C. Pickering, E.M., after a varied experience in Peru, Mexico, and Rhodesia, has returned to New York to be with The Exploration Co., Ltd., 111 Broadway.

1904. F. W. Watson, E.M., since September, 1913, has been manager of the Mikado mine, Gilmore, Idaho, a silver-lead property undergoing development by capitalists of Portland, Ore.

1905. Webster L. Benham, C.E., of Oklahoma City, Okla., has recently been elected President of the Oklahoma Engineering Society, which is interesting itself in the question of good roads and highway engineering.

1906. Cecil Pocock, E.M., for the last five years engaged in mining in Peru, was married, Feb. 3, to Miss Gwen Sutton-Flack, of London. He is now taking a six-months' trip in Europe and the United States.

1906. Matthew Van Siclen, E.M., is engaged in zinc mining at Rush, Marion county, Ark.

1906. John A. Church, Jr., E.M., connected with the Great Falls plant of the Boston & Montana company, visited New York in January with his wife and infant daughter.

1906. J. B. Tenney, E.M., in the geological department of the Copper Queen Company, Bisbee, Ariz., is the author of an article in the *Engineering and Mining Journal,* Feb. 28, 1914, describing the porphyry copper ore deposit in Sacramento hill, Bisbee.

1906. Herman E. Kreuder, E.E., formerly with the Westinghouse company, at Wilkinsburg, Pa., has returned to New York. Address: 31 Forley St., Elmhurst, L. I.

1906. Herbert C. Enos, E.M., City of Mexico, is now in practically

supreme charge of all the mines of the American Smelting and Refining Co., in Mexico.

1906. Robert McL. Johnson, E.M., who has been studying geology at the University since giving up his position as Manager of the Adventure mine, Greenland, Mich., is now on the staff of the Oliver Iron Co., at Hibbing, Minn.

1907. H. C. Atwater, C.E., is with Alexander Potter, Consulting Engineer, So. Church St., New York. Mr. Atwater formerly had charge of work in San Antonio, Tex., and Springfield, Mo., but is now engaged at the home office and has settled in New York.

1908. A. W. Newberry, E. M., and R. E. McConnell, E.M., 1910, are connected with a placer operation at Tumco, Cal.

1908. P. L. Roberts, E.M., lately engaged in the mining of asphalt in Oklahoma, is now engineer with the Standard Paint Co., 100 William St., New York, dealing particularly with the company's water-proofing products.

1909. P. W. Gaebelein, E.M., is the author of a valuable article in the *Engineering and Mining Journal,* Feb. 28, 1914, describing the cyanide plant of the Cornucopia mine, Cornucopia, Ore., of which he is mill superintendent. He visited New York in February.

1909. G. M. Richards, E.M., as Chef de Mission for the Cie. des Chemins de Fer du Congo Superieur aux Grands Lacs Africains, is engaged in geological exploration and examination of placer deposits in eastern Belgian Congo, with office at Uvira, via Dares-Salaam. He was recently elected member of the Mining and Metallurgical Club, associate of the Institution of Mining and Metallurgy, and fellow of the Royal Colonial Institute, all of London.

1909. Benton Overman, E.M., formerly at the Ida H. mine, Laverton, Western Australia, passed through New York in January on his way to London. He left London shortly to return to Bolivia. Address: Porco Tin Mines, Ltd., *Casilla* 52, Potosi, Bolivia.

1909. W. Morgan Carpenter, C.E., formerly with the New York Central & Hudson River R. R., is now with the well known firm of engineer contractors, Jacobs and Davies, and is in charge of the track laying on the Center Street portion of the new subway-bridge loop, New York.

1910. Homer L. Carr, E.M., left New York on Feb. 20, to examine a mine in Honduras.

1910. L. A. Parsons, recently with the Dome mine, Porcupine, Ont., is now mining engineer with the Canadian Copper Co., Copper Cliff, Ont.

1910. J. I. Kane, E.M., recently at the A. S. & R. Co.'s plant at Charcas, S. L. P., Mex., is now at the central office of the company in Mexico City, under H. C. Enos, '06. He visited New York in December, 1913.

1910. C. F. Schnepp, E.M., lately on the geological staff of the Canadian Copper Co., at Copper Cliff, Ont., returned to New York in January.

1910. John W. Maller, E.M., has given up his position with the New York & Honduras Rosario company, and has returned to the University for an advanced course in geology.

1910. J. E. Rypinski, E.M., in January, went to San Mateo, Costa Rica, as engineer for the Aguacate Gold Mining Co.

1911. E. H. Harder, C.E., is employed by the Concrete-Steel Engineering Co., and was recently made resident engineer in charge of the construction of a bridge over the Hudson River, at Glens Falls, N. Y. He was married, Dec. 29, 1913, to Rosina M. Raymond, at East Orange, N. J.

1911. Jos. N. Murray, E.E., was married, Feb. 5, 1914, to Agnes M. Denike, at the North Presbyterian Church, New York. Arthur J. Holman, and Richard Kinsman, both members of the same class, were ushers at the ceremony. After a trip through the South, Mr. and Mrs. Murray made their residence at 746 St. Nicholas Ave., New York.

1911. Samuel Melitzer, E.M., has given up his position as shift boss at the Ray Consolidated, of Arizona, and is going to occupy a similar position at the Braden mine, Rancagua, Chile.

1911. A. E. Hall, E.M., of the Canadian Copper Co., Creighton Mine, Ont., visited New York in January.

1911. Ralph Blumenfeld, Mech.E., formerly with the General Electric Co., at Lynn, Mass., is now sales engineer with the H. P. Hill Corporation, 30 Church St., New York. He was recently elected junior member of the A. S. M. E.

1911. A. A. Leach, E.M., is at San Javier, Sonora, Mex., conducting operations for the Sonora Exploration and Metals Co.

1911. Edward A. Tschudy, Chem.E., is fuel chemist in the standards testing laboratory of the City of New York, having resigned from the Western Electric Co., in April, 1913.

1911–14. Charles R. Fettke, A.M., Ph.D., is instructor in geology and mineralogy in the Carnegie Institute of Technology, Pittsburg, Pa.

1911. Clinton Brettell, Mech.E., left the Locomobile Co. of America, to take charge of the lubricator department of L. Sonneborn Sons, 262 Pearl St., New York.

1912. Robert A. Semple, E.M., is engineer with the Easton-Pacific Co., at Virginia City, Mont.

1912. Karl B. Lamb, Chem.E., is with the U. S. Conditioning and Testing Co., 360 West 22d St., New York, in particular charge of the paper testing department. An article by him on "Tests for Determining the Quality of Paper" appeared in the issue of *Paper,* for Dec.

17, 1913. In the summer of 1913, he was stationed at the U. S. Bureau of Standards, to learn the methods practiced there, and has since been conducting investigations on the expansion and contraction of paper under varying atmospheric conditions.

1913. F. J. Patchell, E.M., is on the engineering corps of the Canadian Copper Co., at Copper Cliff, Ont.

1913. W. M. Grant, E.M., Patton, Pa., spent a few days in New York in January, perfecting arrangements to enter a coal mining enterprise in partnership with other Columbia men in the Clearfield district, Pa.

1913. Frank H. Wagner, E.M., is assistant to the chief engineer of the Lehigh Valley Coal Co., at the Wilkesbarre office.

1913. Carl Trischka, E.M., is on the surveying staff of the Cananea Consolidated Copper Co., at Cananea, Sonora, Mex.

1913. Albert H. Israel, Mech.E., is mechanical engineer and purchasing agent for the Engineering Supervision Co., of New York. He was recently elected junior member of the American Society of Mechanical Engineers.

1913. Thomas F. Githens, Mech.E., has been investigating the well-water resources of Williamsburg, for the American Sugar Refining Co., and is now in charge of reconstruction work at one of the company's filter houses, including the installation of a Lillie quadruple effect evaporator.

Chas. Selden Hicks, C.E., 1911, died at the Flushing hospital on Dec. 10, 1913, from accidental poisoning by bichloride of mercury. He was a resident of Bayside, L. I., where his family have lived for years. He attended school there, and graduated from the Flushing High School in 1907. He then entered Columbia, following the course of civil engineering, and while there was a great favorite among those members of his class who knew him, being generally known around the Campus as "Sunny Jim." While in college he was known as a hard worker, who attended seriously to his studies. He was an honored member of the Zeta Psi fraternity.

On graduating in 1911, Mr. Hicks took a short vacation, starting at work shortly on the motor parkway, on Long Island, where he staid until the parkway was completed. He then went to the motordrome speedway, at Newark, N. J., working there about three months. Following this he was employed by the New York Central Railway in the division engineer's force, first working on the Harlem Division, but was later transferred to the West Shore line, with headquarters at Walden, N. Y. In all he was with the New York Central about a year and a half, having advanced rapidly with them, and being in line for promotion when he died.

Mr. Hicks' friends will always remember him as a big, robust, good-

natured fellow, full of life and fun, and those who knew him can testify that in his death Columbia has met with a great loss.

Arthur Michael Johnson, E.M., 1906, was killed about Feb. 15, by falling in the shaft of the mine of which he was engineer, at Morococha, Peru. He leaves a wife and three children, who were residing in the United States at the time of his death.

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MODERN BITUMINOUS SURFACES AND BITUMINOUS PAVEMENTS.*

BY ARTHUR H. BLANCHARD.†

Although bituminous pavements have been in use in American municipalities for nearly fifty years, the introduction of modern bituminous surfaces and bituminous pavements in the construction of highways outside of built-up districts is of comparatively recent origin in America, dating from about 1906. This point is well illustrated by the fact that in 1908 the total yardage of bituminous surfaces and bituminous pavements constructed under the jurisdiction of the eight leading state highway departments in the eastern United States was only 416,700. Since that date, growth in the use of bituminous materials for the construction and maintenance of roads and pavements has been exceedingly rapid.

To avoid misunderstandings, the various methods of using bituminous materials discussed in this paper will be explained by the following definitions:

Bituminous surfaces are those consisting of superficial coats of bituminous materials, with or without the addition of stone or slag chips, gravel, sand, or similar materials.

Bituminous macadam pavements are those consisting of broken stone and bituminous materials, incorporated by penetration methods.

Bituminous gravel pavements are those consisting of gravel and bituminous materials incorporated by penetration methods.

Bituminous concrete pavements are those having a wearing sur-

* Presented before the Canadian and International Good Roads Congress at Montreal, Canada, May 20, 1914.

† Professor of Highway Engineering in Columbia University, New York City.

face composed of stone, gravel, sand, etc., or combinations thereof, and bituminous materials incorporated by mixing methods.

The definitions of bituminous surfaces and bituminous concrete pavements stated above have been advocated for adoption in the reports of the special committee on "Bituminous Materials for Road Construction and Standards for their Test and Use" of the American Society of Civil Engineers; while the fundamentals of the above definition of bituminous macadam pavements are embodied in the following quotation from the 1913 report of the Association for Standardizing Paving Specifications: "If the stone is spread in place and the bituminous cement or binder applied afterwards, the resulting product is bituminous macadam." As sheet asphalt pavements have been in use for many years and as the essentials of good construction have been well established, this type of bituminous pavement will not be dealt with in this paper.

Bituminous Surfaces.

Since the formulation of the fundamental principles of successful construction of tar surfaces by the engineers of the Department of Roads and Bridges, of France, in 1903, bituminous surfaces have been used extensively in Europe. As an illustration may be cited the construction of 5,000,000 sq. yd. of tar surfaces in a single county of England, in 1911, under the supervision of H. P. Maybury, County Surveyor of Kent. During the past eight years, American engineers have used bituminous materials in this method of construction and maintenance of roads and pavements.

In the case of broken stone and gravel roads, the most efficient method of procedure is to clean the surface thoroughly by sweeping with hand brooms, or horse sweepers and hand brooms, the final sweeping being done with bass or other fine-fibre brooms. The bituminous material, which is generally heated, is applied to the surface in amounts varying from 0.25 to 0.50 gal. per sq. yd., with the aid of pouring cans, hose attached to tanks, hand-drawn gravity distributors, horse-drawn or motor-truck gravity or pressure distributors. Some kind of mineral coating is generally applied to cover the bituminous material. The degree of cleanliness of the surface obtained by sweeping will depend to a large extent upon the details of the original construction. It has been found that a road with a

thoroughly rolled and well puddled broken-stone wearing surface, composed of road metal from 1 in. to 2.5 in. in longest dimension, may be easily cleaned, and the essential adhesion of the bituminous surface readily secured. This method is characteristic of the modern practice of many of the foremost English and French engineers.

Considerable development has taken place in the use of different kinds of bituminous materials. Tars, of both water-gas and coal-gas types, continue to be used to a large extent. Without doubt, the most comprehensive specifications for the construction of bituminous surfaces with tar are those adopted by the Road Board of England. A growing objection has been noted to the use of certain asphaltic oils which require from two to three weeks to "set up" to such an extent that tracking will not occur.

Bituminous Macadam and Bituminous Gravel Pavements.

Bituminous macadam and bituminous gravel pavements are of many types, one of the primary differences in construction being the use of one or two applications of the bituminous material. The efficacy of many of the types depends upon the combinations of sizes of broken stone or gravel, and the combinations of bituminous materials used when two applications are employed. Variations in types also exist dependent upon the manner in which the different courses may be filled, and the treatment of the filled course prior to the application of the bituminous material. The one-application method, in its simplest form, is similar to the construction of a bituminous surface, except that the bituminous material is applied upon a much more open surface. In the case of the two-application method, in certain instances an attempt is made to build up a two-course pavement, while in others the second application is in reality used as a seal coat.

Two of the main difficulties in the construction of bituminous macadam pavements have been to secure a thoroughly compacted wearing course of non-segregated broken stone, and a uniform application of the bituminous cement so that the broken stones in the wearing surface would be uniformly bound together. In connection with the above statement should be noted the following excerpt from the 1914 report of the special committee of the American Society of Civil Engineers: "An important factor for successful results (in

the construction of bituminous pavements by the penetration method) is the thorough compaction by rolling of the road metal before the spreading of the bituminous material."

Two methods which have given satisfactory results will be cited as examples of modern practice.

When the metalling in the wearing course consists of a naturally graded aggregate, ranging in size from 0.5 to 1.25 in., it has been found unnecessary further to fill the voids by the application of a finer product before the first application of bituminous material. The character of the material referred to above is shown by the following mechanical analysis:

Passing ½-in. screen	18.9%
Passing ¾-in. screen	43.1
Passing 1-in. screen	34.4
Passing 1¼-in. screen	3.6
	100.0%

After the wearing course has been thoroughly rolled, from 1.25 to 1.75 gal. of bituminous material per sq. yd. is uniformly distributed. Stone chips, free from dust, are then distributed to fill the surface voids. After the chips are rolled, a seal coat of 0.5 to 1.0 gal. of bituminous material per sq. yd. is applied. The pavement is finished by the rolling of a second application of stone chips.

The second method to be described is what the writer considers the most satisfactory type of bituminous macadam pavement at present constructed in England. This bituminous pavement is known as "Pitchmac" and was designed by John A. Brodie, City Engineer of Liverpool. The following description of the standard method employed in Liverpool is given by Mr. Brodie:

Pitch-grouted macadam has been found to give most satisfactory results in streets of medium and light traffic, and is now being largely used in place of ordinary macadam, and also of more expensive pavements. It is laid to a depth of from 3½ to 4½ in., in two layers. Welsh granite macadam is used, broken to a 2½-in. gauge for the lower layer and to 1½ in. for the top surface. Each layer is put down dry and continually rolled before and after the grouting of pitch and sand mixture has been applied, until the surface is thoroughly consolidated. The foundation is generally of hand-pitched rock, 10 in. deep, as for ordinary macadam, but in some cases a bed of 6-in. concrete has been used on main roads. Pitch macadam is also being much used as a surface covering for old boulder pavements, many of which still exist in Liverpool in old streets where the traffic is very small. The cost of pitch macadam may be taken at 1s. (24c.) per sq. yd. per in. of depth.

Bituminous Concrete Pavements.

Bituminous concrete pavements other than sheet asphalt, and pavements laid by companies as proprietary articles, have received more attention during the past three years than at any time since the days of Abbot, Leverich, Scrimshaw, and Van Camp. Less fear of litigation proceedings and the introduction of economical mixing machines equipped with heating attachments have exerted a marked influence. Furthermore, the rapidly growing recognition of the inherent advantages of bituminous pavements constructed by the mixing method has been largely instrumental in its adoption for traffic conditions for which it is believed to be economical and suitable. Bituminous concrete pavements, in which broken stone forms an integral part of the mineral aggregate, may be divided into three classes.

The simplest type has a mineral aggregate composed of one product of a crusher, that is, a product, in the usual type of portable crushing and screening plant, which passes over one screen and through the larger holes of the adjacent screen. This broken stone, in certain cases, may be fairly uniform in size, but usually is not so. In the writer's opinion, an essential feature in the construction of this type of bituminous concrete pavement is the use of a crusher product ranging from 1.0 to 1.25 in. in size. As an illustration, will be cited a mechanical analysis of a product obtained from a plant where the broken stone passed over a 0.5-in. screen and through a 1.25-in. screen:

Passing ⅛-in. screen	1.2%
Passing ¼-in. screen	4.2
Passing ½-in. screen	34.7
Passing ¾-in. screen	40.6
Passing 1-in. screen	17.3
Passing 1¼-in. screen	2.0
	100.0%

It is apparent that the above product would not be referred to as composed of uniformly sized stone. It is of interest to note that certain bituminous concrete pavements, having a width of 25 ft., constructed with this broken stone product in 1911 have been subjected to an average daily mixed traffic of 2000 to 3000 vehicles, and are at present in excellent condition with no maintenance charges to date.

This type of bituminous concrete pavement has been constructed

for many years by using either one or, in certain cases, several courses of broken stone mixed with bituminous cement. As an illustration of the latter method will be cited the practice of one large construction company which builds this type of pavement. The first, or bottom course, of metal coated with bituminous cement ranges from 1.25 to 2.5 in.; the second course, from 0.5 to 1.25 in.; and the third course, from 0.25 to 0.5 in. The pavement is finished with a dressing of uncoated chips.

Asphalts, tars, and tar-asphalt compounds have been used for the bituminous cement. In some cases one kind of bituminous material has been used in the mix and another kind for the seal coat; one of the most common combinations is tar in the mix and asphalt for the seal coat.

As illustrating some of the details of construction of this type of bituminous concrete pavement which should be covered in contracts, excerpts from specifications recently drafted by Mr. Prevost Hubbard and the writer for the New York State Department of Efficiency and Economy will be cited. It should be borne in mind that the temperatures, and other limitations specified, apply to the bituminous cements and mineral aggregate covered in other sections of the specifications.

Broken stone for the bituminous concrete shall be heated, as directed, before entering the mixer, to between 66° C. (150° F.) and 149° C. (300° F.) in revolving dryers in which no flame shall be permitted to come in contact with the broken stone and in which the broken stone shall be continuously agitated during the heating.

The asphalt cement or refined tar shall be heated in kettles so designed as to admit of even heating of the entire mass, with an efficient and positive control of the heat at all times. Asphalt cement shall be heated as directed to a temperature between 135° C. (275° F.) and 177° C. (350° F.). All asphalt cement heated beyond 177° C. (350° F.), either before or during mixing with the broken stone, shall be rejected. Refined tar shall be heated as directed to a temperature between 93° C. (200° F.) and 135° C. (275° F.). All tar heated beyond 135° C. (275° F.), either before or during mixing with the broken stone, shall be rejected.

When thoroughly heated to the temperature directed, the asphalt cement or refined tar and the broken stone for the bituminous concrete shall be mixed so that the resulting mixture shall contain between 5 and 7½ percent. by weight of bitumen as directed. A mixer shall be used, having revolving blades, and so designed and operated as to produce and discharge a thoroughly coated and uniform mixture of non-segregated broken stone and asphalt cement. When discharged, mixtures of asphalt cement and broken stone shall have a temperature not more than 149° C. (300° F.) and not less than 93° C. (200° F.) as directed. When discharged, mixtures of refined tar and broken stone shall have a temperature not more than 121° C. (250° F.) and not less than 66° C. (150° F.), as directed.

The bituminous concrete, heated and prepared as specified, shall be delivered direct from the mixer to the point of deposition on the foundation in

trucks or wagons, provided with canvas covers for retaining the heat. As delivered the bituminous concrete shall have a temperature of at least 66° C. (150° F.) Material having a lower temperature than this shall not be laid upon the foundation.

Rollers used on the bituminous concrete and the seal coat shall be well balanced, self-propelled, tandem rollers, weighing between 10 and 12 tons each. Each shall have a compression under the rear roller of between 200 and 350 lb. per linear inch of roll, and shall be provided with an ash pan, which shall prevent ashes from dropping on to the bituminous concrete or seal coat.

As soon as possible after the compaction of the bituminous concrete, when the surface is clean and dry, a seal coat of the hot asphalt cement shall be evenly distributed over the bituminous concrete and spread by means of squeegees as directed. The asphalt cement shall be applied at a temperature not less than 135° C. (275° F.), nor more than 177° C. (350° F.), at a rate of 0.5 to 1 gal. per sq. yd., as directed. A thin, uniform layer of dry, clean, No. 1 broken stone (stone chips) shall be immediately spread over the asphalt cement, as directed, by machines or skilled workmen. The spreading of the No. 1 broken stone shall not lag more than 20 ft. behind the placing of the ashpalt cement coating. No. 1 broken stone shall not be placed on the wearing course before the asphalt cement of the seal coat is applied. The surface of the bituminous concrete shall be kept scrupulously clean until the seal coat is applied, and the contractor shall not permit any nauling over the wearing course before the completion of the seal coat.

No bituminous concrete shall be mixed or placed between Oct. 1 and May 15, except by written permission, and no bituminous concrete shall be mixed or placed when the air temperature in the shade is below 10° C. (50° F.), nor when the foundation is damp or otherwise unsatisfactory.

The second type usually consists of a single broken stone product of a crusher, and sand, or other fine mineral matter, mixed together with a bituminous cement. The wearing surface of this mix is sometimes finished by rolling in fine stone chips, but generally a seal coat is used, together with fine mineral matter for a top dressing. When constructed on a commercial scale, the mineral aggregate is always heated and mixed in a specially constructed machine. Usually the same grade and type of bituminous material is used for the mix and the seal coat.

In the third type of bituminous concrete pavement the composition of the mineral aggregate is definitely covered in properly drawn specifications. As an example may be cited the following specifications for the mineral aggregate of Warrenite, a proprietary pavement of the Warren Brothers Co., which was used by William H. Connell, Chief of the Bureau of Highways, in drafting specifications for the City of Philadelphia.

Material passing 1.25-in. screen and retained on No. 2 sieve, 40 to 60 percent. Material passing No. 2 sieve and retained on No. 4 sieve, 10 to 20 percent. Material passing No. 4 sieve and retained on No. 10 sieve, 10 to 5 percent. Material passing No. 10 sieve and retained on No. 30 sieve, 10 to 5 percent. Material passing No. 80 sieve, at least 25 percent. of which will pass a No. 200 sieve, 10 to 5 percent. The balance, to pass No. 30 sieve and be retained on No. 80 sieve.

The 1914 specifications of the State of New Jersey contain the following mechanical analysis of a bituminous concrete pavement similar to the one given above.

	Minimum	*Maximum*
Passing 1½ and retained on 1-in. screen.....	0%	15%
" 1 " " " ½-" "	40	50
" ½ " " " ¼-" "	10	25
" ¼ in. and retained on a 10-mesh sieve.....	8	15
" 10 " " " " 30- " "	12	22
" 30 " " " " 80- " "	5	15
" 80 " " " " "200- " "	3	8
" a 200-mesh sieve	2	8
Bitumen content	6.5	8.5

As another illustration may be cited the well known Topeka specification, which covers a definite grading of a mixture of broken stone and sand. The Topeka grading is as follows:

Percentage of bitumen .....from	7 to 11
" " mineral aggregate passing 200-mesh screen... "	5 " 11
" " " " " 40- " " ... "	18 " 30
" " " " " 10- " " ... "	25 " 55
" " " " " 4- " " ... "	8 " 22
" " " " " 2- " " ...less than	10

In the construction of all types of bituminous concrete pavements, in addition to the requirements covering the properties of the bituminous cement and the quality and character of the mineral aggregate, certain essential features should be given careful consideration. The following citations from the 1914 report of the special committee of the American Society of Civil Engineers are especially pertinent:

Where the character of the traffic justifies the use of a bituminous concrete pavement, the same conditions demand an extraordinarily strong foundation therefor.

The amount of bituminous material to be used in any case will depend upon the peculiar conditions of that case, such as the kind of road metal and of bituminous material, the character of the aggregate, the climatic conditions, etc.

The character of the mineral aggregate to be used may be controlled by local conditions, but the best results can be obtained only by the use of the best materials. Excessive sizes, or excessive variations in the size of the mineral particles, should be avoided, and the utmost care must be taken to avoid the segregation of the different sized particles.

Mixing machines should be used, and hand-mixing methods should be avoided wherever practicable.

In the use of a heated aggregate for the construction of a bituminous concrete pavement, non-uniformity or excess in the heating of stone should be avoided.

Where bituminous pavements are laid, the edges should be protected and a sudden transition from the pavement to any softer shoulder material avoided by means of cement concrete or other edgings and such reinforcement of the shoulder material as may be necessary.

MICROSCOPIC TESTS ON OPAQUE MINERALS.

BY EVEREND L. BRUCE.*

The determination of opaque minerals when occurring as small grains in rocks, or when in intimate association in ores, is one of the difficult and uncertain problems of mineralogy. The translucent and transparent minerals yield to well known microscopic methods, but thus far few such tests have been devised for the opaque minerals. Considerable work has been done by different investigators, largely, however, with the purpose of ascertaining the paragenesis of known minerals rather than determining unknown ones. It is the purpose of this paper to combine the various tests devised by those who have worked along this line with a few additional methods that seem applicable to the problem, in an attempt to construct at least a partial determinative scheme.

Among the early articles on the subject is one by William Campbell, (*Economic Geology*, Vol. 2, pp. 350-366) giving the following distinguishing characteristics for the minerals studied:

Magnetite.— Steel gray color. Polishes well. Etches along parting planes, often yielding gridiron structure. H = 5½ to 6½.
Chalcopyrite.— Yellow color. Polishes easily. H = 4.
Pentlandite.— Light bronze color. Polishes better than pyrrhotite; not so brittle. Sometimes shows distinct cleavage. Distinguished from pyrrhotite by etching. H = 4.
Pyrite.— Pale brass color. Polishes with difficulty. Usually shows scratches. Polishes in relief. H = 6 to 6½.
Pyrrhotite.— Light bronze color similar to pentlandite. More brittle than pentlandite and shows a pitted surface. H = 4. By immersing a specimen in hot HCl (1:1) pyrrhotite is attacked, while pentlandite is not.

Campbell and Knight used the method of polishing and etching on various Cobalt ores, but no definite determinative tests are recorded.

Bastin, in his paper on metasomatism in sulphide enrichment, records the fact that polybasite with strong HNO_3 is not etched so readily as chalcocite, but slowly exhibits a yellowish brown color with a slight iridescence in places. Chalcopyrite similarly treated shows a faint peacock tarnish.

The most detailed work on the identification of opaque minerals is that of F. C. Lincoln. He has examined the gold ores and constructed a scheme for the determination of most of the several gold minerals, as follows, (o = no effect):

* Department of Mineralogy, Columbia University, New York.

Mineral.	Color.	Texture	HNO_3 (1:1)	HNO_3 (1:2)	HNO_3 (1:4)	HCl (1:1)	With Hg.
Gold	Deep yellow	Smooth	o	o	o	o	Amalg.
Chalcopyrite	" "	Rough	o	o	o	o	o
Pyrite	Pale yellow	Slightly rough	Black tarn.	Black tarn.	o	o	o
Marcasite	" "	" "	" "	" "	o	o	o
Pyrrhotite	Pale reddish yellow	Very rough	o	o	o	o	o
Calaverite	Pale yellow	Smooth	Bronze tarn.	Bronze tarn.	o	o	o
Sylvanite	" "	"	" "	" "	o	o	o
Nagyagite	White	"	Gray tarn.	o	o	o	o
Petzite	"	"	Brown & blue tarn.	Brown & blue tarn.	o	Gray tarn.	o
Hessite	"	"	" " " "	" " " "	o	" "	o
Galenite	"	"	" " " "	" " " "	Brown & blue tarn.	" "	o

Etching by means of an electric current produced by a small platinum triangle has been tried by Beijerinck with the following results:

Cassiterite.— Deposit of black metallic tin.
Chalcopyrite.— Becomes black.
Pyrite and Pyrrhotite.— Not affected.

In constructing a scheme from these tests and from others that were devised, the object aimed at was the determination of minute grains of mineral. This was not always successfully done. Some of the results depend on chemical reactions which it is as yet impossible to localize, and to that extent the results obtained are uncertain. A brief statement of the methods of preparation of the specimens and of obtaining the special results will be followed by a summary in schematic form.

Preparation of the specimen.— The polishing of the mineral is fully described by Campbell in *Economic Geology,* Vol. I, p. 751, but for completeness, a brief summary is given here. A fairly flat specimen is chosen, if possible, and this is ground to a plane surface on a horizontally rotating iron lap, armed with medium-grade carborundum. After a thorough washing, the specimen is treated on a copper lap with No. 100 emery until the grooves of the coarse grinding are erased. This is followed by No. 200 emery, until the scratches of the No. 100 powder disappear. In all cases the specimen is rotated to prevent unequal effect. After washing and drying, the surface is polished on three grades of polishing paper, Nos. 0, 00, 000, mounted either on boards, the motion being produced by hand, or on wooden laps rotated as before. The grinding in each case is continued until the scratches from the previous treatment are removed. The orientation of the specimen in each succeeding treatment should be at right angles to that in the previous one, so that the scratches of the finer paper will be across those of the coarser. After polishing with the finest paper, a lap covered with broadcloth saturated with rouge and water is used for the finishing process. By this means a high polish can be obtained.

Instruments.— The microscope used for this investigation was one with which both inclined and vertical illumination could be obtained. Inclined illumination was secured by a small parabolic mirror at-

tached to the objective; vertical illumination by a movable glass disc in the barrel of the microscope. The source of light for ordinary work was a Welsbach lamp, the light being focussed by a plano-convex lens. For some minerals the light was filtered through a flask of copper sulphate solution, replacing the lens; by this means, light containing no yellow rays can be obtained. For applying chemicals to the polished surface small glass tubes drawn to a fine point are useful. For physical tests, any small fine-pointed instrument can be used.

Methods.— The mineral, prepared as above described, was first examined for color and appearance. For this purpose obliquely incident light gives the best results. Following this, one large specimen was broken into several smaller ones, some of which were treated further, while one was kept for reference. Etching was first tried with strong cold HCl, at half-minute intervals, or less, if much action took place. If unattacked after a reasonable time, strong cold nitric acid was substituted for the hydrochloric. Finally, aqua-regia was used with substances that resisted both single acids.

In the case of minerals that behaved in the same manner under etching, special chemical or physical tests were tried. In chemical tests, the grain to be tested was brought into focus under a fairly low-power objective and touched with an acid capable of etching it. After the action had continued for a short time, a drop of a reagent producing characteristic reactions was added. Under the microscope only very small quantities are necessary, and, with care, rather small grains, can be thus tested. The chief reactions employed are the following:

1. *Iron.* The grain touched with freshly prepared mixture of potassium ferrocyanide and acid becomes deep blue if iron be present.
2. *Nickel.* The mineral is treated with a mixture of HNO_3 and tartaric acids. After evaporation, when touched with a solution of dimethylgloxime freshly made ammoniacal, a brilliant red is obtained from minerals carrying nickel.
3. *Copper.* In the presence of copper, a mixture of HNO_3 and potassium ferrocyanide solution gives a deep red. If iron also be present, this is followed by green.
4. *Manganese.* Most manganese minerals are attacked by HCl with production of a deep brown solution which becomes colorless on addition of hydrogen peroxide.
5. *Silver.* The mineral is treated with nitric acid. Addition of hydrochloric produces a white precipitate. Also true of lead and mercury minerals.
6. *Bismuth.* The mineral is touched with nitric acid followed, after drying, by hydrochloric. A little water will then produce a white precipitate.

Physical Tests.— In a few cases, streak and hardness are useful. These tests can be made with a needle point.

Besides the above, a few other tests were tried. Deposition of silver from weak silver sulphate solutions by certain minerals may possibly be useful as a criterion. An experiment was tried with marcasite and pyrite in a ten-percent. solution. What seemed to be a dendritic growth of silver formed on the marcasite after long immersion, while the pyrite remained bright and unchanged. Further tests with variation of temperature and concentration are necessary, however. The rate of attack in the process of etching is also sometimes a valuable aid in identification.

The scheme outlined below depends for its major division on the color of the polished mineral. In each color division, subdivisions are made by etching tests. Special behavior of different minerals makes further differentiation possible in many cases.

I. MINERAL BY INCLINED ILLUMINATION IS YELLOW.

A. Etched by HCl.

Pyrrhotite. Bronzy yellow. Surface rough. Reacts for Fe.

B. Etched by HNO_3, not by HCl.

(*a*) Without noticeable tarnish or deposit.

Pyrite. Pale yellow. Slightly rough. Reacts for Fe.

Marcasite. Pale yellow. Slightly rough. Reacts for Fe. Precipitates Ag(?).

Millerite. Slightly rough. Reacts for Ni.

(*b*) With tarnish.

Chalcopyrite. Deep yellow. Rough. Reacts for Fe and Cu. Iridescent tarnish.

C. Not attacked by single acids.

Gold. Deep yellow. Smooth. Amalgamates with Hg.

II. MINERAL IS WHITE.

A. Etched by HCl.

B. Etched by HNO_3.

(*a*) With no tarnish or deposit.

Smaltite. Rough with bright facets. Gives Ni test.

Arsenopyrite. Rough with bright facets. Becomes gray with reddish spots. Reacts for Fe, not for Ni.

Leucopyrite. White. Very rough. Reacts for Fe.

Silver. Smooth. Reacts for Ag.

Bismuth. Smooth. Reacts for Bi.

(*b*) With deposit.

Arsenic. Chalky white deposit.

Antimony. Chalky white deposit.

C. Unattacked by single cold acids.

Cobaltite. Slightly rough. Etched by HNO_3.

Niccolite. Slightly rough with reddish tinge. Treated with aqua regia reacts for Ni.

III. MINERAL IS BLACK OR GRAYISH BLACK.

A. Etched by HCl.

Magnetite. Shows intersecting parting planes. Etches easily. Fe reaction.

Franklinite. Fairly smooth. Etches less readily than magnetite.

Ilmenite. Fairly smooth. Etches very slowly.

Hematite. Steel gray. Smooth. Red streak.

Manganite. Dull black. Brown solution.

Psilomelane. Brown and black areas. Brown solution.

Braunite. Black. Etches to bluish black. Brown solution.

Alabandite. Smooth grayish black. Very easily attacked (40 sec.).

Pyrolusite. Black fibrous surface. Soft. Brown solution.

B. Etched by HNO_3, not by HCl.

(*a*) Without tarnish.

Enargite. Dull grayish black. Etches to fibrous structure. Cu test.

Argentite. Smooth dull black. Ag test. Sectile.

Stephanite. Smooth dull black. Ag test.

(*b*) With a tarnish.

Chalcocite. Smooth black. Etched to a bluish tarnish, later becoming peacock colors.

Bornite. Pitted. Purple color. Etches to a peacock tarnish. Reacts for both Fe and Cu.

(*c*) With a deposit.

Galena. Smooth black. Etches easily, with a yellow deposit.

Bournonite. Smooth dull black. Etches easily, with yellowish opalescent deposit. Cu test.

Sibnite. Smooth dull black. Etches fairly slowly to a fibrous structure with a chalky deposit.

Tetrahedrite. Smooth. Bluish black. Etches with an opalescent deposit. Reacts for Cu.

C. Unattacked by single acids.

Molybdenite.

Chromite.

Cassiterite. Black deposit by electric etching

Columbite.

The table as presented is by no means complete, and some of the minerals treated cannot be absolutely determined by the tests recorded, but it is believed that the compilation of what is known will be of distinct advantage.

In conclusion, the writer wishes to acknowledge the advice and assistance of Professor A. J. Moses in the work upon which this article is based.

PHYSICAL PROPERTIES OF STEEL AND CAST-IRON BARS BROKEN AT DIFFERENT TEMPERATURES.

BY HAROLD PERRINE * AND CHAS. B. SPENCER †

This paper includes tests on structural metals at temperatures which often occur in engineering practice. A knowledge of the ultimate strength of cast iron and steel under these conditions is essential in the design of boilers, cylinders, valves, steam-pipe connections, and in determining the limiting thickness of protection for structural iron and steel in fire resistant building construction.

Previous Investigations.

In this connection, little was known until 1836, when a committee of the Franklin Institute, of Philadelphia,[1] made a series of tests on soft steel and wrought iron. The results published by the committee agree closely with what is now believed to be correct. Maximum strength was found at about 500° F., and from there a gradual decrease took place until, at temperatures over 1000°, the metal was much weakened. In 1877-8 two series of experiments were carried on. Those made in Portsmouth dock-yard,[2] dealing only with gun metal, are of value only so far as the apparatus is concerned. The test pieces were heated in an oil bath, and great precautions were taken to make the heating uniform, even the dies for gripping the bar being carefully brought up to the temperature of the test piece. The results are foreign to the purposes of the present tests, and are not given.

Dr. Julius Kollmann[3] in the same year made an investigation of the strength of wrought iron and Bessemer steel. His experiments are valuable chiefly on account of the great care taken to make the results accurate, and while his conclusions are believed to differ from what is usually the case, they must be carefully considered. For purposes of verification, he used two machines of different capacities. The test pieces were heated in a coke fire to the de-

* Of the Department of Civil Engineering, Columbia University.
† C. E., Columbia, 1910.
[1] *Journal* of the Franklin Institute, 1836.
[2] *Engineer*, Oct. 5, 1877.
[3] *Journal* of the Franklin Institute, 1881.

sired temperature and broken as quickly as possible, to eliminate variability of temperature. As soon as the stress was applied to the piece, a duplicate, heated in exactly the same manner and supposedly to the same temperature, was dropped into a copper calorimeter, and the temperature calculated from the rise in temperature of calorimeter and water. No allowance was made for the difference in specific heats of wrought iron and steel.

Kollmann's results indicate the following:

1. Wrought iron retains constant strength until a temperature of 200° F. is reached, at which point a gradual weakening begins. This becomes much more rapid after the temperature reaches 750° F.

2. Bessemer steel behaves in exactly the same way, except that the temperatures at which changes in strength occur are higher. A constant strength up to 400° F. is shown, where a gradual decrease begins, becoming greater at 1000° F.

Knut Styffe (1863) made similar experiments on steel bars of carbon content 0.33 to 1.14%. The tests were conducted at temperatures ranging from —40° to 412° F. The heat was obtained by immersion in a bath and measured by thermometers. The experiments are of value in that the effect of low temperatures is investigated. Styffe found:

1. The absolute strength of iron and steel is not diminished by cold (—40° F.)

2. Between 212° and 392° F., no change takes place in steel.

3. Soft iron undergoes an increase of strength between 212° and 400° F.

Fairbairn[4] describes tests made by him on bars of English rivet iron. The temperatures were indicated by the roughly approximate terms "dull red heat," "visible by daylight," etc. Fairbairn estimated that the maximum strength of English rivet iron is to be found at about 400° F.

J. E. Howard conducted a series of tests on cast iron and steel.[5] The specimens were confined in a sheet-iron muffle and the heat applied by means of a row of gas burners inside the muffle and just below the specimen. The temperature was determined by the

[4] "Useful Information for Engineers."
[5] *Iron Age*, 1890.

expansion of the bar itself. Mr. Howard believed that this method was sufficiently accurate, but, as 5° is only about 0.0002 in. in that length of bar, it seems probable that the error was considerable. Besides the usual error of observation, the measuring apparatus must have been affected by the heat. There was also danger of non-uniformity in heating, and the author admits that the coefficients of expansion vary under high temperatures.

His results show that the strength of steel diminishes, until a point between 200° and 300° is reached, where it again increases to about 500°. From here on, the metal begins to weaken and the strength decreases, falling off very rapidly beyond 900°. Harder steel was found to reach its point of maximum strength at a somewhat lower temperature. Cast iron gave nearly constant results at all temperatures up to about 900°, where it began to weaken until it reached a value at 1500°, about one-half of that of the steels.

As to the elastic limit, Mr. Howard did not succeed in getting satisfactory results at high temperatures. His method was to observe the point where a marked increase in elongation for a constant increment of load took place. As far as he could determine, the elastic limit varied as follows:

Elastic Limit Percent.	*Temperature Deg. F.*
100	70
88	334
76	492
49	934

Reduction of area was found to decrease up to the point of maximum strength, after which it again increased until, at very high temperatures, it was nearly 100%. Elongation Mr. Howard considered to be the permanent set in the metal outside of the locality of fracture. He observed that elongation was greatest at ordinary temperatures. In the present tests, however, it has been found impossible to limit the region of fracture, so that elongation is considered as permanent stretch in the 1.5 in. including the fracture. Mr. Howard found great variation in different bars.

More recent experiments are those conducted by Prof. M. Rudeloff.[6] Small bars about 10 cm. long and 1 cm. diameter were heated in baths of steam (100° C.), naphthalin vapor (200° C.),

[6] *Proceedings* of the International Association for Testing Materials, August 26, 1909.

and naphthylamine vapor (300° C.) Temperature was measured by thermo-electric couples, either placed against the bars or within similar specimens placed beside them. The ends of the bars were threaded and inserted in tension rods, so that the bar itself was not in the grips. Elongation was determined by the Martens mirror apparatus, the stretch of the bar between given points being used to tip the mirror. Care was taken to make the rapidity of loading uniform.

Professor Rudeloff's values confirm closely the results obtained by Knut Styffe (1863). Soft Bessemer steel showed a decrease in tensile strength at 50° C., where it again increased, giving a maximum at about 250°. From here on, the decrease was rapid. The elastic limit was found to decrease steadily with increasing temperatures. Elongation behaved in the same way up to about 150°; beyond that there was a rapid increase. Soft open-hearth steel with low carbon (0.20%) behaved similarly to soft Bessemer. Cast iron was found to retain its strength up to 400° C., where it began to fall off rapidly until, at 600° C., 60% had been lost.

The latest data upon this subject were published by Messrs. Bregowsky and Spring of the laboratory of the Crane Co., Chicago, Ill.[7] While the authors do not claim perfection in method and results "from the theorist's standpoint," their researches are of interest chiefly in view of the fact that a wide range of metals are included. They were the first investigators, by the way, who extended the work among materials subjected to torsional stress.

Description of Method.

The present investigations were carried on in the Materials Testing Laboratory of Columbia University, New York City. The apparatus, Plates I and II, was designed by Professor Ira H. Woolson, who had been conducting experiments along similar lines. The usual form of Rhielé testing machine, of 100,000-lb. capacity, with attachments for tension and driven by a motor, was used. The furnace to give the temperature is set up right in the machine. Thus, there is no difference between the conditions under which the bars are heated, and those under which they are broken. The furnace consists of a porcelain tube, 2 in. inside diameter and 1 ft.

[7] *Proceedings* of the International Association for Testing Materials, 1912.

long, around which is wound about 25 ft. of platinum wire at ¼-in. pitch. Fuller's earth is packed about the wiring and the whole covered with steam-pipe lagging, so that the entire furnace, when

PLATE I

completed, is in the form of a hollow cylinder 2 in. inside diameter, 8 in. outside diameter, and 12 in. long. A bracket, made of iron strips and bolted to the frame of the testing machine, is provided for a support. The temperature of the furnace is raised by passing a 110-volt lamp circuit, at 4 to 8 amperes, through the platinum wire, the extremities of which are carried out through the insulating material of the furnace. This temperature is controlled so effectively by a variable resistance placed in series with the line, as to keep it constant for indefinite periods. Before placing the furnace in the machine, an indicator bar of material identical to

the test-piece is suspended within the porcelain tube. By this device the temperature of the test piece is known. It is read by a thermo-electric couple placed within the bar; one of the wires is

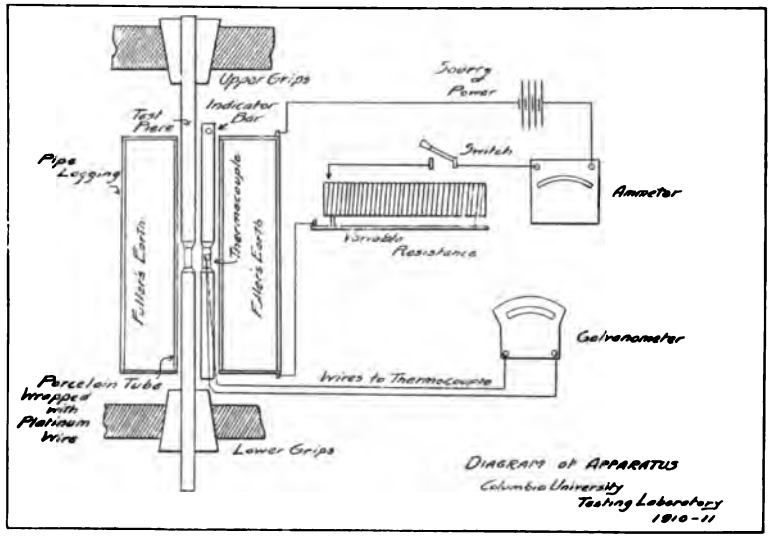


PLATE II

platinum and the other platinum-iridium. They are attached to a Siemens-Halske galvanometer of capacity 180 mil-volts = 2400° F. This was previously calibrated.

The test piece is inserted beside the indicator bar after the apparatus is in place and the porcelain tube is packed tightly at its ends with asbestos wool, to eliminate all air currents. A current of 8 amperes is sent through the furnace until a temperature about 50° below the required point is reached. It is then shut off, and an opportunity given to the bars to get as hot as the furnace. The whole is then brought slowly to the desired point. For each temperature there is a certain current which will hold the heat to the exact value for an indefinite length of time. Ten minutes is considered long enough to ensure uniformity of heating, and when the temperature has remained stationary for that length of time, the load is applied until fracture takes place. In all cases, the bars are allowed to cool in air. The speed in applying the load was such that the head moved at about 0.6 in. per minute. It was found by

trial that the application of a load of 5 lb. was sufficient to throw the beam out of balance, so that about 20 lb. per bar or 100 lb. per square inch is the maximum error.

In all cases, the maximum strength was recorded and an attempt was made to obtain the yield point by the "drop of the beam." For steel at low temperatures this is not difficult. As the temperature increases, this point becomes less and less marked, so that beyond 600° its determination was impossible. Elongation was measured in a gauged length of 1.5 in. including the point of fracture. Reduction of area was measured in the usual manner.

All test pieces were 26 in. long, $\frac{3}{4}$ in. diameter, reduced to $\frac{1}{2}$ in. for $1\frac{1}{2}$ in. at the center. This reduction is accomplished in $\frac{1}{2}$ in. on each end, so that the slope of the fillet is 1 in 4. Plate I shows the position of the bars in the apparatus, about 4 in. in the grips at each end, 2 in. clear at each end, and the remaining 12 in. in the furnace. The center of the reduced section is adjusted to be in the center (longitudinally) of the furnace. The apparatus and the method of procedure are especially interesting in view of the facility of manipulation.

The materials tested were Bessemer steel (two grades), cast iron, and cast steel. The steel was furnished by the Carnegie Steel Co., of Pittsburg, Pa., and gave the following analysis:

	Carbon	*Phosphorus*	*Manganese*	*Sulphur*
Medium	0.23	0.010	0.42	0.025
High	0.39	0.021	0.40	0.032

The cast iron of the first set, which was furnished by the Essex Foundry, of Newark, N. J., contained 2.69% total carbon. The cast steel was furnished by the Isaac Johnson Co., of Spuyten Duyvil, N. Y., and had 0.196% carbon content.

Observations are compiled in the adjoining table, elongation and reduction of area being stated in percentages, and ultimate strength in pounds per square inch.

Material	Observation	Temperature, Fahrenheit									
		75°	200°	300°	400°	500°	600°	700°	800°	900°	1000°
Bessemer Steel. (C = 0.39%)	Elongation	34.33	31.30	26.44	25.33	26.00	31.55	41.77	47.77	50.67	52.66
	Reduction of area..	56.63	54.84	50.59	49.90	48.78	50.16	65.58	78.54	83.34	89.57
	Ultimate strength...	72,530	66,940	71,030	73,550	75,380	74,780	67,400	54,015	43,920	32,580
Bessemer Steel. (C = 0.23%)	Elongation	43.33	31.00	31.33	27.11	29.11	32.89	45.78	54.72	55.33	61.18
	Reduction of area..	67.28	61.03	60.12	56.78	57.60	61.69	72.76	82.03	86.91	91.63
	Ultimate strength...	59,955	59,255	63,620	69,060	69,400	65,908	56,880	44,953	35,160	26,315
Cast Steel. (C = 0.196)	Elongation	27.33	.....	.....	25.78	21.67	26.45	.....	31.11	.....	49.00
	Reduction of area..	36.99	.....	.....	41.64	37.51	38.36	.....	51.85	.....	80.17
	Ultimate strength...	81,310	.....	.....	73,180	74,580	77,930	.....	63,520	.....	36,450
Cast Iron No. 1. (C = 2.69)	Ultimate strength...	21,140	.....	.....	20,490	.....	19,500	.....	17,750	18,720	12,810
Cast Iron No. 2.	Ultimate strength...	.....	.....	.....	.....	.....	29,940	.....	30,010	25,360	20,200

BESSEMER STEEL (HIGH).

Ultimate Strength.— The 0.39% carbon steel showed at room temperature (75° F.) a tensile strength of 72,530 lb. per sq. in.

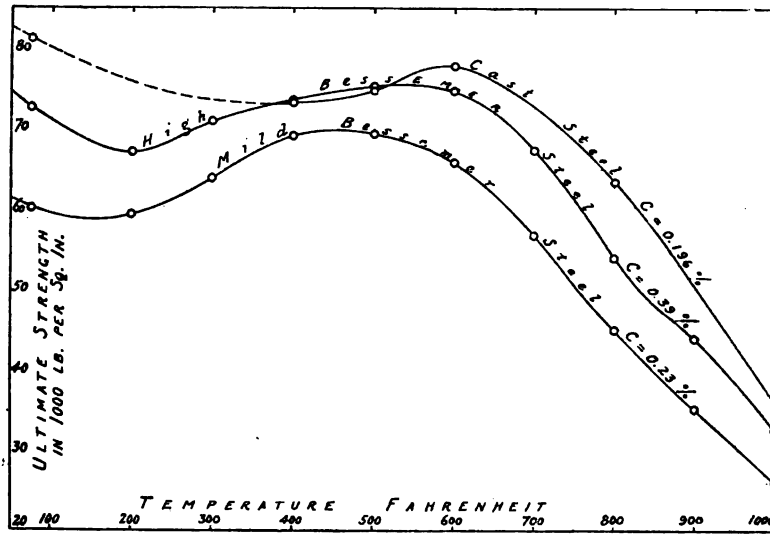


PLATE III

(Plate III). At 200° there was a loss of about 8%, a minimum for this region. From here the curve rose until at 500° it reached a point about 4% higher than at room temperature. Remaining

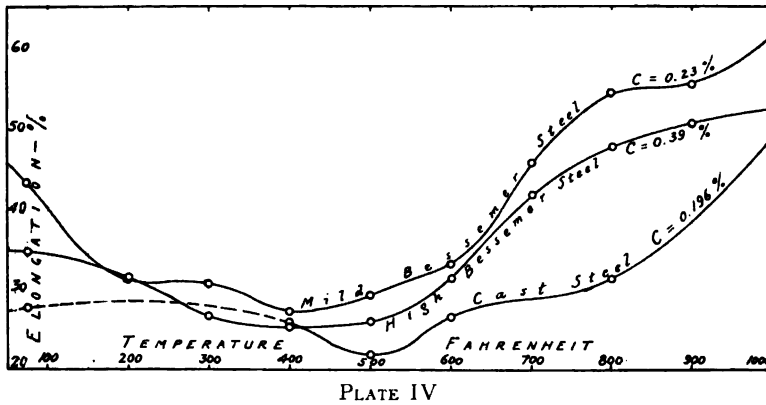


PLATE IV

nearly constant between 500° and 600°, the strength fell rapidly until at 1000° it had only 45% of its original value.

Elongation.— The elongation of the reduced section at room temperature was 34.33%. The value then decreased until 400° was reached, where a minimum of 25.33% was obtained. From 300° to 600° the variations were small, but beyond that the rate increased rapidly until at 1000° it reached 52.66%. (Plate IV).

Reduction of Area.— The curve follows closely that of elonga-

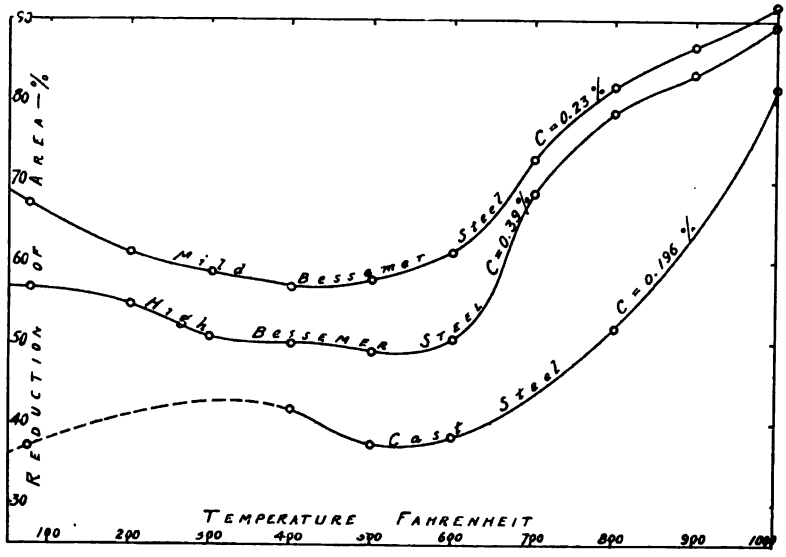


PLATE V

tion except that the minimum appears to be reached at a slightly higher temperature. At 75° the reduction was 56.63% and the maximum at 1000° was 89.57%. (Plate V).

BESSEMER STEEL (MILD).

Ultimate Strength.— The 0.23% carbon steel showed at room temperature (75° F.) a tensile strength of 59,955 lb. per sq. in. (Plate III). With a loss of about 1% at 200°, mild steel reaches a maximum of 69,400 lb. per sq. in. at 500°, which represents an increase over that at room temperature of about 16%, as against a gain of 4% in the case of the high steel. An explanation of this is offered later. Beyond the maximum points the curves are nearly parallel up to 1000°, both being slightly concave upward.

Elongation.— The elongation curve for the mild steel shows a marked drop between room temperature and 200° (Plate IV).

Between 200° and 600° the curves are closely similar, but beyond this point the lower-carbon metal begins to draw out much faster. The slope of the curves at 1000° seems to indicate that the divergence of the two curves will be greater beyond this point.

Reduction of Area.—Except for a greater drop between room temperature and 200°, the curve is similar to that of the higher steel. Above 700° the curves have almost exactly the same slope. (Plate V).

The micrographs [8] shown in Plates VI, VII, VIII, IX, are immediate regions of fracture at 75°, 200°, 500° and 1000° respectively, of the medium steel specimens. The bar broken at 500°, giving maximum strength, shows least change in structure. This might be expected as elongation of the photographed bars in this case

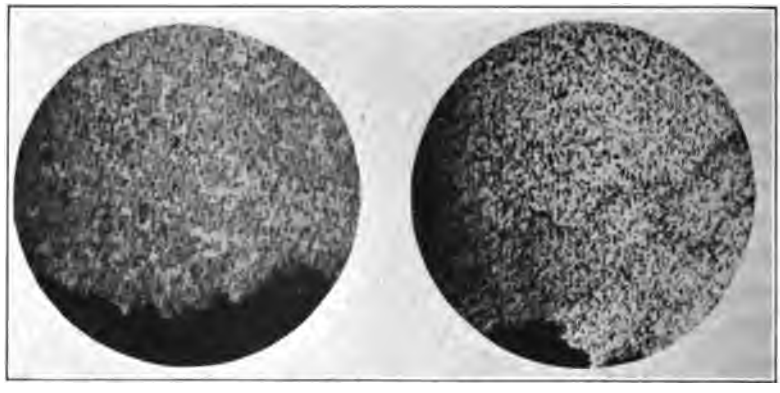


PLATE VI

Medium Steel broken at 75° F., showing medium elongation.

PLATE VII

Medium Steel broken at 200° F., the First Low Point on the Strength Curve.

was the least. It will be noticed that the pearlite has not started to elongate at this point. At 1000° the well defined and converging lines of flow clearly show the effects of elongation and reduction of the metal. Plate VII is a section taken at 200°, the first point of minimum strength. The lines of flow, while clearer than in VIII do not show a deformation such as is evidenced in the case of 1000°. Plate X is a section of normal medium steel as received.

[8] All the microsections prepared for this paper were etched with a 5% solution of picric acid in absolute alcohol.

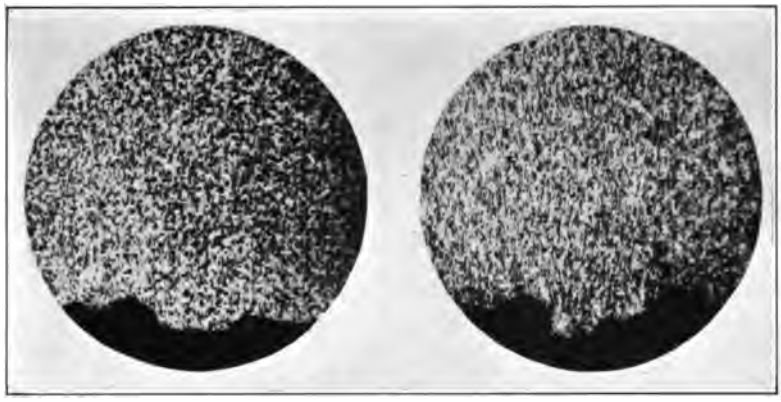


PLATE VIII
Medium Steel broken at 500° F., showing Least Elongation and giving Maximum Strength.

PLATE IX
Medium Steel broken at 1000°, showing Marked Elongation and Reduction, and giving Minimum Strength.

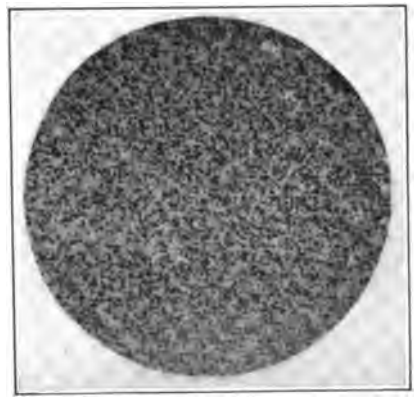


PLATE X
Medium Steel, as Received.

Character of Fracture.— The fractures in all cases were cup shaped and were more perfectly so as the temperatures increased. After breaking at lower temperatures the bars could be fitted together, but at 900° and 1000°, failure seems to have taken place more readily in the interior of the metal, so that both portions were cup shaped. In all cases the appearance was silky.

Location of Fracture.— In several previous investigations[9] it has been found that at higher temperatures the test pieces always

[9] Professor Ira H. Woolson.

failed near the upper fillets. This was asserted to be due to the fact that the circulation of the air caused the temperature to be greater at the top than at the bottom of the furnace. In that case, the bars would break at the top where the metal was weaker. We found, however, that the difference in temperature was not sufficient, in the 1½ in. of reduced section to overcome the effects of irregularities in consistency of the metal, and the minute differences in cross section, so that there seemed to be no uniformity in the location of fracture.

Cast Iron.

A great deal of difficulty was experienced in obtaining any uniformity whatsoever in the case of cast iron. The results, while accurate as far as they go, do not embrace a sufficient number of

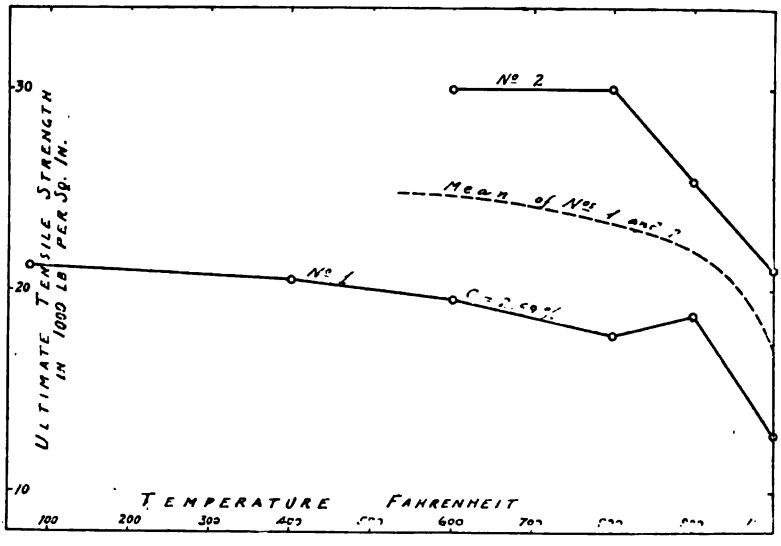


Plate XI

tests adequately to determine the strength of such an erratic material. Two sets of bars were used (Plate XI), one having strength about 20,000 lb. per sq. in. (room temperature) and the other about 50% stronger. The weaker set was tested first, when it became at once apparent that an insufficient amount of material was at hand to give reliable results. The curve shows a gradual falling off in strength up to 600°, where the loss increases more rapidly.

From 800° to 900° an increase is shown, but this is highly improbable. Only two bars were broken at 800° and these results vary by 1700 lb. per sq. in. Thus, if the weaker of the two bars be discarded, the increase from 800° to 900° would practically disappear. Moreover, the increase is not shown in the case of the

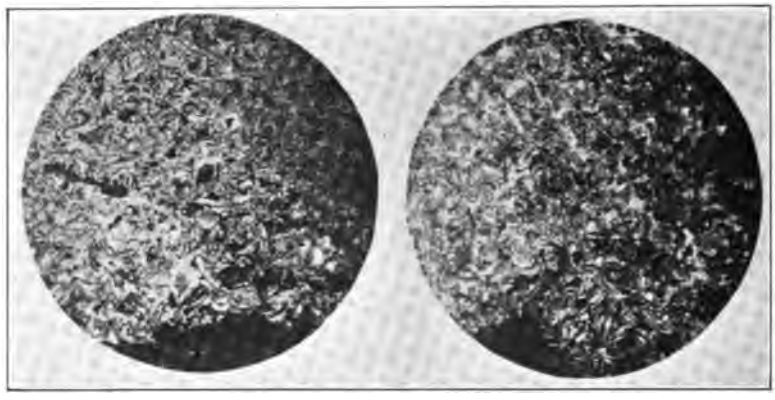


PLATE XII
Cast Iron (1) broken at 75°.

PLATE XIII
Cast Iron (1) broken at 1000° F., showing Remarkable Similarity to that broken at 75° F.

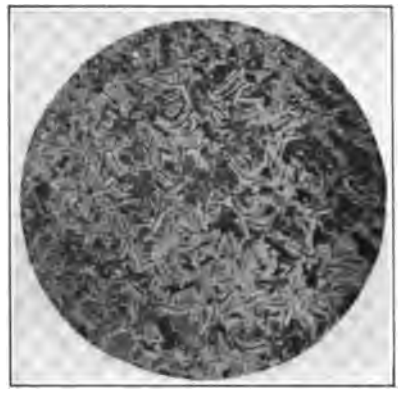


PLATE XIV
Cast Iron (1) as Received.

other set of iron which was afterwards tested to verify this region.

This second set shows a curve practically horizontal between 600° and 800°, and then a straight-line drop to 1000°. From the two sets of bars we may conclude that cast iron is affected slightly by temperatures up to a point between 800° and 900°, but that from

there on the loss in strength is rapid. A hypothetical curve, the mean of the two sets, is shown dotted. Two micrographs were made of bars of the first set broken at 75° and 1000° respectively. A comparison of Plates XII and XIII shows that the deformation at 1000° is no greater than at room temperature. Plate XIV shows a normal section of the first set of cast iron, as received.

Cast Steel.

Ultimate Strength.— In the case of cast steel an insufficient number of bars were available to make tests at 200°, 700°, and 900°. An examination of the curve (Plate III), however, will show that these omissions leave no doubt of its accuracy except in the region below 400°. This portion of the curve is drawn by analogy to that of high-carbon Bessemer steel, which it closely resembles at the higher temperature. It is shown by broken line.

Unlike the Bessemer steels, the maximum strength is found at room temperature, as in the case of cast iron. At 400° there has been a loss of 10%; this is believed to be the minimum point for this region. At both 400° and 500° the strength of cast steel is less than that of the Bessemer steel (C = 0.39). At 600° a maximum of 77,930 lb. per sq. in., 96% of the room-temperature strength, is reached. Beyond this point the strength falls off similarly to the Bessemer steels.

Elongation.— The elongation curve (Plate IV) shows a minimum value at 500°. Between room temperature and 400° the broken-line curve is drawn with a slight rise. The slope between 400° and 600°, together with the shape of reduction curve for the same region, makes this rise probable. At the higher temperatures the elongation increases like that of the Bessemer steels.

Reduction of Area.— The curve is almost exactly the reverse of that of ultimate strength (Plate V). The value at room temperature is not again reached, though closely approached at 500°.

An examination of the Bessemer steel curves shows a minimum elongation and reduction corresponding to a maximum strength. The low point in the strength at or near 200°, however, seems to have no effect on the elongation or reduction. In the case of cast steel, a maximum of both is found corresponding to this low point.

Micrographs XV, XVI, XVII, and XVIII were made of frac-

tured sections of cast steel at 75°, 400°, 600° and 1000°, respectively. Section XIX was taken outside the region of fracture and

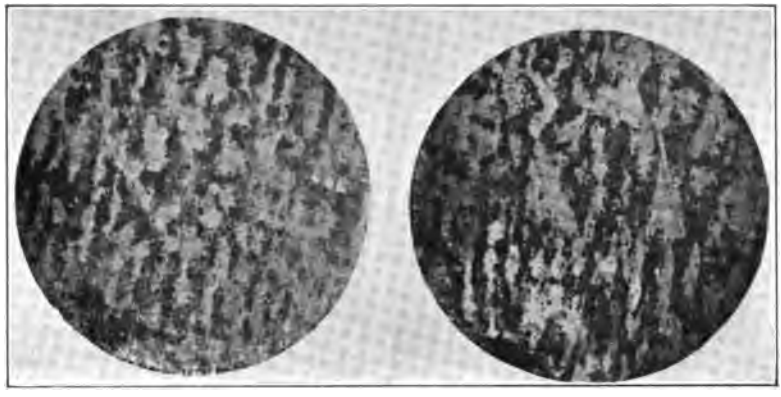


PLATE XV

Steel Casting broken at 75° F., the Point of Maximum Strength.

PLATE XVI

Steel Casting broken at 400° F., the First Point of Low Strength.

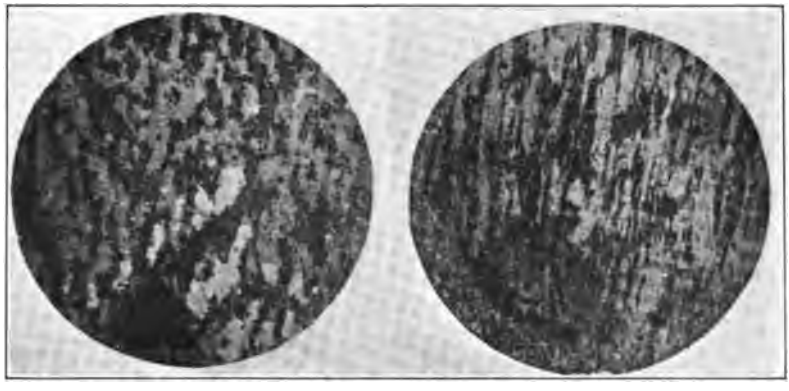


PLATE XVII

Steel Casting broken at 600° F., giving Increased Strength and Decreased Deformation.

PLATE XVIII

Steel Casting broken at 1000° F., showing Marked Elongation and giving Minimum Strength.

represents normal steel. In comparing this with the other micrographs, it is seen that the flow of the metal is greatest in XVIII and low in XVII, which is the point of maximum strength.

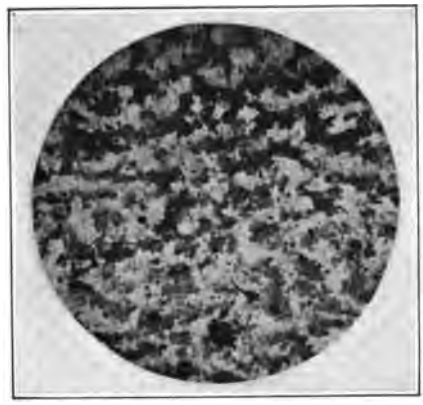


PLATE XIX
Steel Casting as Received.

Character of Fracture.— Except for a tendency to become cup-shaped at the highest temperatures, the fractures were in all cases irregularly crystalline. This irregularity was greatest at 600°.

Throughout, the change of color is much more marked than in Bessemer steel. A temperature of 400° gives a pale straw color; 500° a yellow bronze; and 600° a deep blue, usually much intensified in the fracture. At 800° the color resembles that at 600°, except that it is less brilliant and less intense in the fracture than elsewhere. At 1000° the color is that of the oxide which covers the metal and the blue has entirely disappeared.

CONCLUSIONS.

Mr. C. R. Roelker[10] offers a plausible explanation of the behavior of metals under heat. It is well known that cast iron, cast steel, and rolled steel are subject to internal stresses, cast iron and cast steel due to uneven cooling, and rolled steel due to the different amounts of work expended upon different parts of the bar. These stresses have an important effect in decreasing the strength of the material, although this is generally overbalanced, in the case of the rolled materials, by the strengthening effect due to increase in density. It is also well known that annealing reduces these stresses, and increases the ductility of the metal. It might then be expected that all metals would be materially stronger at higher temperatures. That the action is not simply one of reduction in in-

[10] *Journal* of the Franklin Institute, October, 1881.

ternal stresses is shown by the fact that cast iron and cast steel are not thus strengthened. The fibrous character of the material appears to be the important factor. As the steel is rolled, the fibres are deformed. At about 500° the action of the heat has been to cause the fibres to change their relative positions temporarily, so that if the bar is actually broken at that temperature it exhibits increased strength. If the bar be cooled again, the fibres return to their original position. As the temperature increases beyond 500°, the same action takes place, but is offset by the weakening effect of the repulsive action of heat on the molecules.

The curves amply confirm the above theory. The increase for low-carbon Bessemer steel is greater than for the higher-carbon metal, while in wrought iron (Prof. Woolson) the increase in strength is nearly 50%. This shows that the more fibrous the character of the metal the greater is the action of heat in increasing its strength.

The term "fibrous character" must not be taken too literally. Wrought iron is, of course, essentially fibrous, but it is generally conceded that material of the class of Bessemer steel is not. The expression is chosen in contradistinction to that of "granular" which is the term usually applied to cast iron.

While a knowledge of the behavior of metals under these conditions is necessary, some definite proof should be developed which will demonstrate conclusively the *reason* for the variation in strength. Possibly, if the bars be quenched while still at the testing temperature, and micrographs made, such facts will be ascertained. Again, a criticism of this method is that the appearance of the section due to internal stresses induced by quenching would be entirely changed from its condition at the time of fracture.

In any case the strength of each of these materials is directly dependent upon the respective cohesion existing between its component molecules, each metal or alloy having its own definite properties and curves.[11] As the temperature changes, this cohesion is, of course, affected and consequently the strength as well. There are other conditions, mentioned above, which have a direct bearing upon this variation, the most important being the presence of internal stresses due to more or less rapid cooling. Even cool-

[11] Booraem "Internal Energy."

ing in air at ordinary temperature will be conceded to be fairly rapid, so that we may expect internal stresses to be induced in this case as in quenching, but to a much less degree.

The presence of these internal stresses will control, therefore, to a greater or less extent, the shape of the curve for any particular metal or alloy. From this we may expect irregularities in the graphs for the same material, depending on the several heat treatments to which they have been subjected. We suggest that the low points formed in the case of rolled steel in the neighborhood of 200° represent the condition of maximum internal stress due to cooling. To determine definitely whether this assumption be true, bars of the same composition, which have undergone different practical heat treatment, should be tested.

We should not lose sight of the fact that maximum internal stress may not necessarily exist at room temperature. In observing the elongation and reduction curves of the two grades of Bessemer steel we see no break at or near 200° to correspond to the low point in the strength curve. This leads us to believe that they are more representative of the normal behavior of the metal. In other words, the induced stresses in this case effect the strength but have appreciably less effect on the ductility.

It may be remarked how consistently the cast steel curves strike averages between those of cast iron and rolled steel. An examination of the strength curves, for example, shows us in the case of cast steel the characteristic fall and rise of a ductile material. Its similarity to cast iron we see in its property of never rising above room-temperature strength.

We desire to express our appreciation of the courtesy shown us during the preparation of this paper by Professors Ira H. Woolson, James S. Macgregor, Charles P. Berkey and William Campbell, in placing their respective laboratory equipments at our disposal, and to Mr. J. F. Davis, of R. W. Hunt & Co., for analyses of the cast iron and cast steel specimens.

SAFE ECCENTRIC LOADING OF RIVETS.

BY JOSEPH DI STASIO.*

Notation.—

n = total number of rivets.

r = number of vertical rows of rivets.

p = pitch of rivets in any vertical row.

d = distance between vertical rows of rivets.

e = eccentricity of load from center of gravity of group of rivets.

R = maximum safe value of one rivet in either shear or bearing

W = total safe load.

H = force of extreme couple parallel to horizontal axis 1 — 1.

H' = force of extreme couple parallel to vertical axis 2 — 2

$$= H\frac{z}{z'} = H\frac{dr}{p}\left(\frac{r-1}{n-r}\right) \text{(see analysis)}$$

Other notation as indicated in analysis.

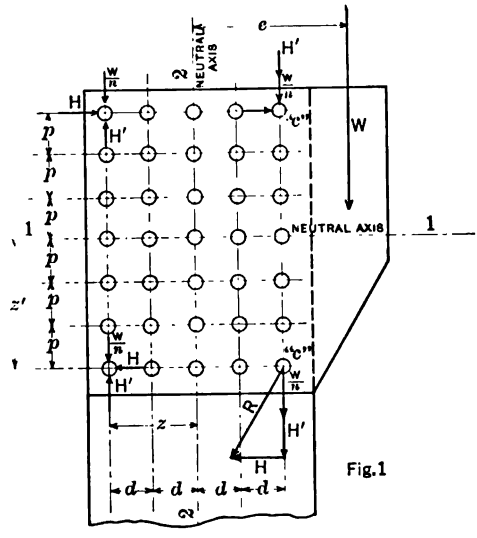


Fig.1

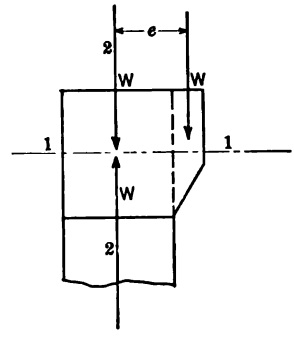


Fig.1a

In Fig. 1 the number of spaces (p) either below or above horizontal axis 1 — 1 may be expressed by the general formula

$$\frac{1}{2}\left(\frac{n}{r}-1\right)=\frac{n-r}{2r};$$

and the number of spaces (d) either to the left or right of vertical axis 2 — 2 by the general formula $\frac{1}{2}(r-1)$.

* C. E., Columbia, 1913. Designing engineer with the Fagan Iron Works, Jersey City, N. J.

In Fig. 1a we may replace the eccentric load W by an equal force W acting at the center of gravity of the groups of rivets, and a couple of which the moment is We. Assuming an equal distribution of the force W amongst all the rivets, the direct stress on each rivet will be equal to $W \div n$. The eccentric moment We may be replaced by two sets of couples parallel respectively to axes 1 — 1 and 2 — 2. We will also assume that the intensity of stress on the rivets *due to bending alone* varies directly as the distance of the rivet from the center of gravity of the group; which is equivalent to saying that the horizontal and vertical components H and H' vary directly as the distance of the rivet from horizontal axis 1 — 1 and vertical axis 2 — 2, respectively. If we indicate by M_1 the total moment of that set of couples of which the forces are parallel to horizontal axis 1 — 1 and bearing in mind our previous assumption, from Fig. 1 we may write the general expression:

$$\frac{M_1}{2r} = H\binom{\frac{n-r}{2r}}{\frac{n-r}{2r}}\binom{\frac{n-r}{2r}}{}p + H\binom{\frac{n-r}{2r}-1}{\frac{n-r}{2r}}\binom{\frac{n-r}{2r}-1}{}p + H\binom{\frac{n-r}{2r}-2}{\frac{n-r}{2r}}\binom{n-r}{2r}-2\Big)p + \ldots\ldots\ldots\ldots etc.$$

which, by ordinary methods of simplification, reduces to

$$M_1 = \frac{Hp}{(n-r)}\Big[(n-r)^2 + (n-3r)^2 + (n-5r)^2 + \ldots etc.)\Big] \ldots . (1)$$

In like manner, if we let M_2 equal the total moment of the set of couples of which the forces are parallel to vertical axis 2 — 2, we shall obtain the following expression (note that the number of horizontal rows of rivets may be indicated by the formula $n \div r$; see also Fig. 1 and paragraph 1 of this article).

$$\frac{M_2}{2n} = H'\binom{\frac{r-1}{2}}{\frac{r-1}{2}}\binom{r-1}{2}d + H'\binom{\frac{r-3}{2}}{\frac{r-1}{2}}\binom{r-3}{2}d + H'\binom{\frac{r-5}{2}}{\frac{r-1}{2}}\binom{r-5}{2}d + \ldots\ldots\ldots\ldots etc.$$

$$M_2=\frac{2\,n\,H'\,d}{r\left(\frac{r-1}{2}\right)4}\left[(r-1)^2+(r-3)^2+(r-5)^2+\ldots\ldots etc.\right]$$

Since we have assumed that the horizontal and vertical components vary directly as the distance of rivet from axes 1 — 1 and 2 — 2, respectively, from Fig. 1,

$$H'=H\frac{z}{z'}=\frac{\left(\frac{r-1}{2}d\right)}{\left(\frac{n-r}{2r}p\right)}=H\frac{d}{p}\frac{r\left(\frac{r-1}{n-r}\right)}{}$$

Substituting this value of H' in above equation,

$$M_2=\frac{H\,d^2\,n}{p\,(n-r)}\left[(r-1)^2+(r-3)^2+(r-5)^2+\ldots\ldots etc.\right]\ldots.(2)$$

As indicated in Fig. 1, we note that the extreme rivets marked "c" will have the maximum stress, consequently if R denotes the allowable value of one rivet either in bearing or shear,

$$R=\sqrt{\left(\frac{W}{n}+H'\right)^2+H^2}\ldots\ldots\ldots\ldots\ldots\ldots\ldots(3)$$

From equations (1), (2), and (3) we may derive a general equation as follows:

We first must simplify the series which occurs in equation (1), namely:

$$f(y)=(n-r)^2+(n-3r)^2+(n-5r)^2+\ldots\ldots\ldots\ldots(4)$$

$$=n^2-2nr+r^2+n^2-6nr+9r^2+n^2-10nr+25r^2$$
$$+\ldots\ldots etc.\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(5)$$

The above series may be divided into three simpler series, as follows:

$$n^2-2nr+r^2+n^2-6nr+9r^2+n^2-10nr+25r^2+\ldots. etc.=$$
$$\begin{cases} n^2+n^2+n^2+\ldots\ldots\ldots etc.=S_1 \\ -2nr-6nr-10nr-\ldots etc.=S_2 \\ r^2+9r^2+25r^2+\ldots\ldots. etc.=S_3 \end{cases}$$

If l = number of terms in series of equation (4)

$$S_1=ln^2\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(6)$$

Also, $S_2=-2nr-6nr-10nr-\ldots. etc.=-nr(2+6+10+14+\ldots\ldots etc.)$.

The above is an arithmetic series; consequently we may express the summation:

$$S = \frac{l}{2}\,[2a + (l-1)b]$$

where a = first term = 2 in this case.

b = common difference = 4 in this case.

Substituting,

$$S = \frac{l}{2}\,(4 + (l-1)4) = \frac{l}{2}\,(4 + 4l - 4) = 2l^2.$$

Therefore $S_2 = -2nrl^2$ ..... (7)

The last minor series:

$$S_3 = r^2 + 9r^2 + 25r^2 + 49r^2 + \ldots\text{etc.} = r^2\,(1 + 9 + 25 + 49 + \ldots\ldots \textit{etc.}).$$

As before, if l = number of terms in equation (4) we have the following relation between l and S_3:

l	1	2	3	4	5....etc.
$S_3 \div r^2$	1	10	35	184	165....etc.

To find the general equation of this series let us apply the general equation of the parabola, and assume three arbitrary values of the series as follows:

l	1	3	5
$S_3 \div r^2$	1	35	165

The general equation of the parabola

$$y = v + al + bl^2 + cl^3 + \ldots\ldots \textit{etc.} = S_3 \div r^2$$

We readily see that for our series $v = o$. Substituting the three arbitrary values of l and $S_3 \div r^2$ chosen above, we may then write the three simultaneous equations:

$$1 = a + b + c$$
$$35 = 3a + 9b + 27c$$
$$165 = 5a + 25b + 125c$$

which, on solving simultaneously, give the following values for the coefficients: $a = -\frac{1}{3}$; $b = o$; $c = \frac{4}{3}$.

Therefore $\frac{S_3}{r^2} = -\frac{1}{3}l + \frac{4}{3}l^3 = \frac{4}{3}\left(l^3 - \frac{l}{4}\right)$

$$S_3 = \frac{4}{3}r^2\left(l^3 - \frac{l}{4}\right) \ldots\ldots (8)$$

We may now write the expression

$$f(y) = (n-r)^2 + (n-3r)^2 + (n-5r)^2 + \ldots\ldots \textit{etc.}$$
$$= S_1 + S_2 + S_3$$
$$= ln^2 - 2nrl^2 + \frac{4}{3}r^2\left(l^3 - \frac{l}{4}\right) \ldots\ldots (9)$$

To obtain a relation between l, r, and n, from equation (1) and Fig. 1, we see that if

$\frac{n}{r}$ is an even number, then $l = \frac{1}{2}\left(\frac{n}{r}\right) = \frac{n}{2r}$

$\frac{n}{r}$ is an odd number, then $l = \frac{\frac{n}{r} - 1}{2} = \frac{n-r}{2r}$

Substituting the value $l = \frac{n}{2r}$ in equation (9) we obtain

$$f(y) = \frac{n}{2r}n^2 - 2nr\frac{n^2}{4r^2} + \frac{4}{3}r^2\left(\frac{n^3}{8r^3} - \frac{n}{8r}\right)$$

$$= \frac{4r^2n}{3\times 8r}\left(\frac{n^2}{r^2} - 1\right) = \frac{n}{6r}(n+r)(n-r)$$

In a similar manner, when $n \div r$ is odd, substituting the value $l = \frac{n-r}{2r}$ and simplifying, we get

$$f(y) = \frac{n-r}{2r}\left[\frac{nr}{3} + \frac{n^2}{3}\right] = \frac{n}{6r}(n+r)(n-r)$$

Of course it was not necessary to substitute both values for l, since from equation (1) we see that the series is perfectly general whether $n \div r$ is even or odd. Consequently from equation (9) we have:

$$f(y) = (n-r)^2 + (n-3r)^2 + (n-5r)^2 + \ldots etc.$$

$$= ln^2 - 2nrl^2 + \frac{4}{3}r^2\left(l^3 - \frac{l}{4}\right) = \frac{n}{6r}(n+r)(n-r) \ldots\ldots (10)$$

Substituting the value of this series in equation (1)

$$M_1 = \frac{Hp}{n-r}\left[\frac{n}{6r}(n+r)(n-r)\right] = \frac{Hpn(n+r)}{6r} \ldots\ldots (11)$$

From equation (2)

$$M_2 = \frac{Hd^2n}{p(n-r)}\left[(r-1)^2 + (r-3)^2 + (r-5)^2 + \ldots . etc.)\right]$$

and if the above series be compared with the series

$$f(y) = (n-r)^2 + (n-3r)^2 + (n-5r)^2 + \ldots . etc.$$

it is readily seen that the two series are identical in form, and that if r is substituted for n and the numerical coefficient 1 for r in the latter series, we shall obtain the former series. Making this substitution, equation (10) becomes:

$$\left[(r-1)^2+(r-3)^2+(r-5)^2+\ldots \text{ etc.}\right]=\frac{r}{6}(r+1)(r-1)$$

(Note that the evaluation of this series also remains the same whether r is even or odd.) Therefore,

$$M_2=\frac{Hd^2n}{p(n-r)}\left[(r-1)^2+(r-3)^2+(r-5)^2+\ldots \text{ etc.}\right]$$

$$=\frac{Hd^2n}{p(n-r)}\left[\frac{r}{6}(r+1)(r-1)\right]$$

$$=\frac{Hd^2nr(r+1)(r-1)}{6p(n-r)} \quad \ldots\ldots (12)$$

But, $We=M_1+M_2=\dfrac{Hpn(n+r)}{6r}+\dfrac{Hd^2nr(r+1)(r-1)}{6p(n-r)}$

$$=\frac{nH}{6rp(n-r)}\left[d^2r^2(r^2-1)+p^2(n^2-r^2)\right]$$

Whence $H=\dfrac{We\,6rp(n-r)}{n[d^2r^2(r^2-1)+p^2(n^2-r^2)]}$ ..... (13)

From Eq. (3), $R^2=\left(\dfrac{W}{n}+H'\right)^2+H^2$

But $H'=H\dfrac{dr}{p}\left(\dfrac{r-1}{n-r}\right)$

Whence $R^2=\left[\dfrac{W}{n}+H\dfrac{dr}{p}\left(\dfrac{r-1}{n-r}\right)\right]^2+H^2$

$$R^2=\frac{W^2}{n^2}+\frac{2W}{n}H\frac{dr}{p}\left(\frac{r-1}{n-r}\right)+H^2\left[\frac{dr}{p}\left(\frac{r-1}{n-r}\right)\right]^2+H^2$$

Substituting the value

$$H=\frac{We\,6rp(n-r)}{n[d^2r^2(r^2-1)+p^2(n^2-r^2)]} \text{ from eq. (13)}$$

we have

$$R^2=\frac{W^2}{n^2}+\frac{W^2}{n^2}\left[\frac{2e6dr^2(r-1)}{d^2r^2(r^2-1)+p^2(n^2-r^2)}\right]+$$

$$\frac{W^2}{n^2}\left[\frac{e6rp(n-r)}{d^2r^2(r^2-1)+p^2(n^2-r^2)}\right]^2\left[1+\left(\frac{dr(r-1)}{p(n-r)}\right)^2\right]$$

and $W^2=R^2n^2\div\left\{1+2e\left[\dfrac{6dr^2(r-1)}{d^2r^2(r^2-1)+p^2(n^2-r^2)}\right]\right.$

$$\left.+e^2\left[\frac{6dr^2(r-1)}{d^2r^2(r^2-1)+p^2(n^2-r^2)}\right]^2+e^2\left[\frac{6rp(n-r)}{d^2r^2(r^2-1)+p^2(n^2-r^2)}\right]^2\right\}$$

$$\text{Let } j = d^2r^2(r^2-1) + p^2(n^2-r^2)$$

$$k = \frac{6\,dr^2\,(r-1)}{j} = q\frac{dr\,(r-1)}{p\,(n-r)}$$

$$q = \frac{6\,rp\,(n-r)}{j} = k\,\frac{p\,(n-r)}{dr\,(r-1)}$$

Making these substitutions,

$$W^2 = \frac{R^2n^2}{1 + 2ek + e^2(k^2+q^2)}$$

$$\text{and } W = \frac{Rn}{\sqrt{1 + 2ek + e^2(k^2+q^2)}} \quad (14)$$

$$\text{or } W = \frac{Rn}{\sqrt{(ek+1)^2 + e^2q^2}} \ldots\ldots (15)$$

Equation (14) is our general formula wherein W, the safe load, is dependent upon the variables e, n, d, r, and p. Equation (15) is a little easier to use in some special cases when $q = 0$, i.e., when $n = r$.

Special Case I.— Single Horizontal Row of Rivets.— When we have a single row, then $n = r$ and $p = 0$ (Fig. 2).

Therefore;

$$k = \frac{6dr^2(r-1)}{d^2r^2(r^2-1) + p^2(n^2-r^2)} = \frac{6dn^2(n-1)}{d^2n^2(n^2-1)} = \frac{6}{d(n+1)}$$

and $q = 0$.

Substituting in eq. (15) and squaring,

$$W^2 = \frac{R^2n^2}{\left(\frac{6e}{d(n+1)}\right) + 1\Big)^2}$$

$$W = \frac{Rnd(n+1)}{6e + d(n+1)} \ldots\ldots\ldots\ldots\ldots\ldots (16)$$

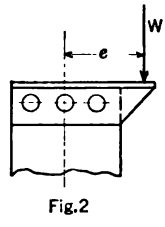


Fig.2

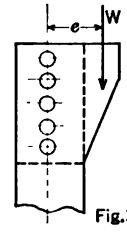


Fig.3

Special Case II.— Single Vertical Row of Rivets.— In this case $d = 0$ and $r = 1$ (Fig. 3).

$$k = \frac{6dr^2(r-1)}{d^2r^2(r^2-1) + p^2(n^2-r^2)} = 0.$$

$$q = \frac{6rp(n-r)}{d^2r^2(r^2-1) + p^2(n^2-r^2)} = \frac{6p(n-1)}{p^2(n^2-1)} = \frac{6}{p(n+1)}$$

Again substituting in eq. (15) and squaring,

$$W^2 = \frac{R^2n^2}{(0+1)^2 + \frac{e^2 36}{p^2(n+1)^2}} = \frac{R^2n^2}{\frac{36e^2}{p^2(n+1)^2} + 1}$$

$$W = \frac{Rn}{\sqrt{\frac{36e^2}{p^2(n+1)^2} + 1}} \qquad (17)$$

TYPICAL PROBLEM.

Suppose it is required to find the safe load W for a condition as indicated by Fig. 4.

Assume: $e = 12$ in. $p = 3$ in. $d = 4$ in. $r = 4$. $n = 12$. Single shear at 10,000 lb. per sq. in.; for ¾ in. rivet, $R = 4420$ lb.

Substituting the values we have:

$$k = \frac{6dr^2(r-1)}{d^2r^2(r^2-1) + p^2(n^2-r^2)} = \frac{6 \times 4 \times 16 \times 3}{16 \times 16 \times 15 + 9(144-16)}$$

$$= \frac{24}{104} = 0.231; \quad k^2 = 0.0533$$

$$q = \frac{6rp(n-r)}{d^2r^2(r^2-1) + p^2(n^2-r^2)} = \frac{6 \times 4 \times 3 \times 8}{104 \times 48}$$

$$= \frac{12}{104} = 0.115; \quad q^2 = 0.0133$$

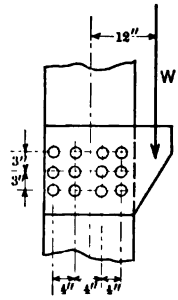


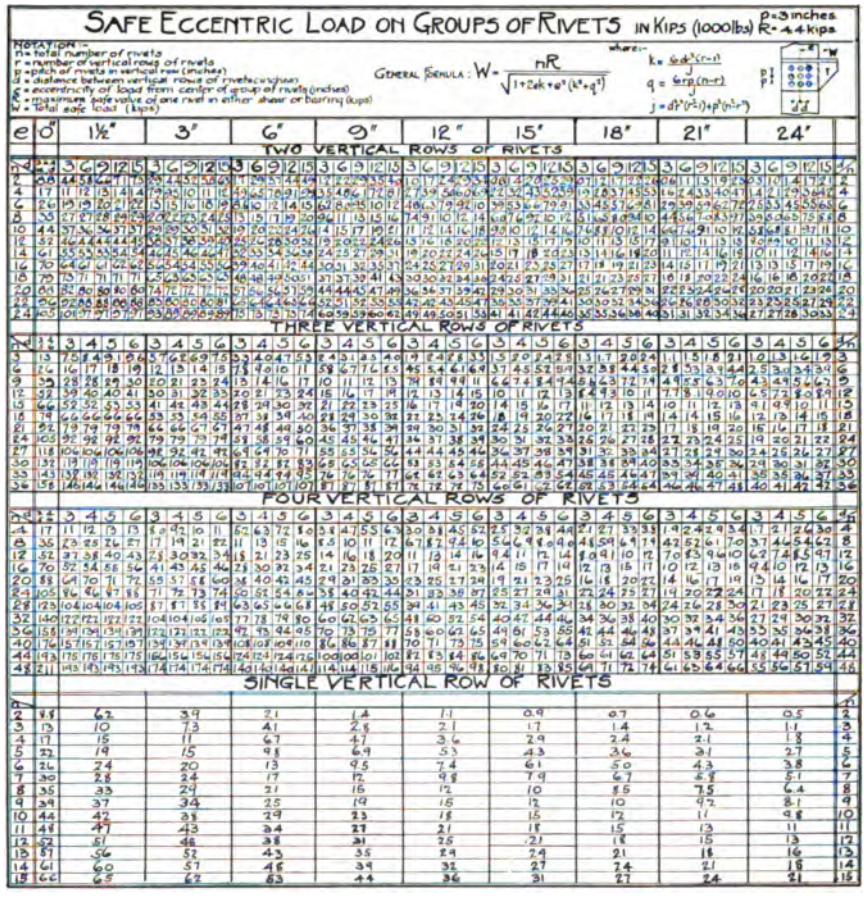
Fig.4

Substituting in general equation (14)

$$W = \frac{Rn}{\sqrt{1 + 2ek + e^2(q^2 + k^2)}}$$

$$= \frac{4420 \times 12}{\sqrt{1 + (2 \times 12 \times 0.231) + 144(0.0533 + 0.0133)}}$$

$$= \frac{4420 \times 12}{\sqrt{1 + 5.55 + 9.6}} = \frac{4420 \times 12}{\sqrt{16.15}} = 13{,}200 \text{ lb. } \textit{Ans.}$$


SAFE ECCENTRIC LOAD ON GROUPS OF RIVETS IN KIPS (1000lbs)
p=3 inches
R=44 kips
NOTATION:-
n= total number of rivets
r = number of vertical rows of rivets
p = pitch of rivets in vertical row (inches)
d = distance between vertical rows of rivets (inches)
e = eccentricity of load from center of group of rivets (inches)
R = maximum safe value of one rivet in either shear or bearing (kips)
W = total safe load (kips)
GENERAL FORMULA: W = nR / √(1+2ek+e²(k²+q²))
where:-
k = 6dn²(r-1) / j
q = 6np(n-r) / j
j = d²n²(r²-1)+p²(n²-r²)
TWO VERTICAL ROWS OF RIVETS
THREE VERTICAL ROWS OF RIVETS
FOUR VERTICAL ROWS OF RIVETS
SINGLE VERTICAL ROW OF RIVETS

It is well to observe here that if we have a rigid connection, for instance of a beam supported on both ends as shown in Fig. 7, although the reaction may be assumed to act at the center of gravity of the groups of rivets, still the rivets will be subject to a bending stress in addition to the direct stress, the intensity of this bending stress depending upon the degree of fixedness of the connection, and subsequent deflection of beam under loading. For a rigidly fixed end connection, the rivets must withstand the negative bending moment induced at end of beam, in addition to the direct stress. A safe method of design is to assume the beam as fixed ended; then, for a uniformly distributed load, the negative bending mo-

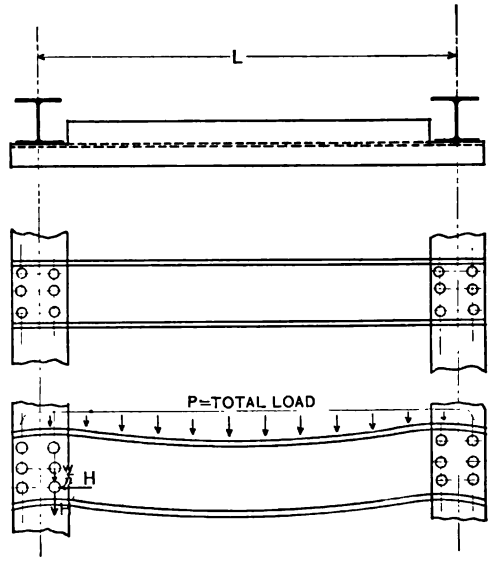


FIG. 5

ment at end of beam $= \frac{1}{12} wL^2 = \frac{PL}{12}$ where $P =$ total load carried by beam.

In the general formula for W, the eccentric moment is indicated by We, therefore,

$$We = 12(PL \div 12) \text{ in.-lb.; but } W = P \div 2$$
$$We = 2WL$$
$$e \text{ (inches)} = 2L \text{ (feet)}$$
$$W = \frac{Rn^2}{\sqrt{1 + 2ck + c^2(k^2 + q^2)}} = \frac{Rn^2}{\sqrt{1 + 4Lk + 4L^2(k^2 + q^2)}}$$

For any other kind of loading a similar method of procedure may be adopted.

THE DEVELOPMENT OF THE SUGAR INDUSTRY.*

BY C. A. BROWNE.†

In previous lectures before the students of this course, the subjects of sugar manufacture,[1] the production of raw sugar in some of our colonial possessions,[2] and the utilization of by-products of the sugar industry[3] were treated. These have all been printed in the SCHOOL OF MINES QUARTERLY, and to save time and avoid repetitions I refer you to this publication for many details. As a topic for this year's lecture, it occurred to me that a short account of the development of the sugar industry would be of interest. The historical study of a subject is usually most instructive; it fixes in our minds the progress of the past and enables us to forecast the possibilities of the future.

Sugar is derived, at present, principally from two plants, the sugar cane and the sugar beet. The production of sugar from the maple, palm, and other minor sources, is of comparative insignificance and will not be touched upon. For the year 1912-1913, the total production of cane and beet sugar for the whole world was 18,144,638 tons, of which 9,178,574 tons was cane sugar and 8,966,-064 tons was beet sugar, being in the proportion of 50.5% for cane and 49.5% for beet sugar. The production of sugar, in order of importance, for the ten leading countries during that year was as follows:

SUGAR PRODUCTION OF THE WORLD.

Country.	*Production of Sugar, Tons.*
1. Germany	2,700,913 (beet)
2. British India	2,583,600 (cane)
3. Cuba	2,428,537 (cane)
4. Austria	1,901,615 (beet)
5. United States and Colonies	1,770,837 (1,146,773 cane; 624,064 beet)
6. Russia	1,374,500 (beet)
7. Java	1,331,180 (cane)
8. France	960,900 (beet)
9. Holland	316,177 (beet)
10. Belgium	298,584 (beet)

* A lecture in the Department of Chemistry, Columbia University, April 17, 1914.

† Chemist-in-charge, New York Sugar Trade Laboratory, 80 South Street, New York.

[1] SCHOOL OF MINES QUARTERLY, April, 1911.

[2] *Ibid*, January, 1913.

[3] *Ibid*, July, 1913.

The consumption of the world's output of sugar in the ten leading countries during the same year was as follows:

SUGAR CONSUMPTION OF THE WORLD.

Country.	*Gross Consumption, Tons.*	*Consumption Per Capita, Pounds.*
1. United States	3,743,150	85.40
2. British India	3,225,000(?)	2.40(?)
3. England	1,966,690	95.52
4. Germany	1,470,000	48.95
5. Russia	1,454,700	24.33
6. France	767,430	43.41
7. Austria	653,300	28.12
8. Turkey	204,000	19.84
9. Italy	166,900	10.76
10. Spain	142,610	16.24

The home of the sugar cane, as of many other of our cultivated plants, is India. We find the cane mentioned in earliest Sanskrit writings and it seems to have thrived there from time immemorial. The Greek soldiers of Alexander the Great found the cane growing in India at the time of their conquest of Asia in 327 B. C., and reports of the sugar cane, which they brought home, are among the first historical accounts that reached Europe. It is doubtful, however, whether sugar was manufactured from the cane so early as this. The cane was at first simply eaten, just as in primitive countries at the present time, the expressed juice being used also as a beverage or fermented into a kind of wine. At a later period cane juice seems to have been evaporated in the household for making preserves or sweetmeats, and the sweet crystalline deposits which separated from the evaporated juice probably gave the early people of India their first ideas of sugar making. It is not until after the third century of the Christian era that we find in old Chinese writings the first mention of sugar as a commodity of commerce, although it is probable that sugar was made on a small scale long before.

From its native home in India the sugar cane was carried Eastward and Westward. It was introduced by the natives through the islands of the East Indies, the Philippines, and the rest of that great archipelago. Thence it was carried to Samoa, Tahiti, and the other islands of the southern Pacific, and from there it was transported by daring native navigators to the Hawaiian Islands, where it was found growing by Capt. Cook at the time of his voyage of

discovery. The Pacific Islanders, however, cultivated the sugar cane simply for the purpose of eating its stalk or drinking its juice; none of them ever advanced far enough to manufacture sugar, and for the development of this art we must turn to the western nations.

The first nation to transport the sugar cane westward was naturally the Persians, whose country adjoined India. The Persians not only grew cane for eating, or for its juice, but also made some progress in sugar manufacture. Traces of Persian influence survive to the present day, as, for example, in our word candy, which is derived from the Persian *kand,* meaning hard or refined sugar. For raw sugar the Persians had a different word, *schakar,* the same as our word sugar, a word very much alike in all languages, and derived from the original Indian or Sanskrit word *sakkara.*

It is to the Arabs, however, that we owe the introduction of the sugar cane to the nations of Europe. The sympathy of Arabian Caliphs with agriculture, the sciences, and the useful arts, was one great means of preserving the civilization of the ancient East and transmitting it to Europe. The Mohammedans, in their conquests of Persia and India, came early in contact with the sugar cane and transplanted it to the conquered nations of the west. Improvements in cultivation and irrigation were introduced, and the familiarity of Arabian alchemists and physicians with the process of recrystallizing salts led them, no doubt, to apply the same principle in refining sugar. In the books of the great Arabian scientist Avicenna, who lived about the year 1000, we find sugar described as we now know it, and from this time onward the use of sugar was destined to increase, until from one of the rarest and most expensive articles of luxury it became one of the cheapest and most abundant commodities.

From the valley of the Tigris and Euphrates the Arabs carried the sugar into Egypt and Palestine and, with the extension of their conquests westward, transported its culture to Asia Minor, northern Africa, to the Mediterranean islands of Cyprus, Rhodes, Crete, Malta, and Sicily, and finally to the continent of Europe itself, where it was widely cultivated in southern Spain, where its culture survives to the present day.

One great factor which favored the introduction of sugar to

Europe was the Crusades. Readers of Joinville's chronicle will remember how the crusaders found the sugar cane growing in Palestine and, like the soldiers of Alexander 1500 years before, brought back stories of the wonderful reed whose sweet juice invigorated them after weary conflict or march. One of the chief benefits of the Crusades was the expansion which followed in the commerce between Asia and Europe, the chief city for the importation of Eastern commodities being Venice. The Venetians improved the art of refining sugar, which they learned from the Arabs, and during all of the 14th and 15th centuries held a monopoly for supplying Europe with sugar.

With the increase in consumption of sugar, the areas for the cultivation of the sugar cane widened. In 1420 the Portuguese transplanted the cane from Sicily to Madeira, and shortly after this time it began to be cultivated in the Canaries, Azores, and other western islands.

Immediately after the discovery of America followed the transplanting of sugar cane to the western hemisphere. Columbus on his second voyage, in 1493, carried with him sugar cane from the Canaries to San Domingo. The cane thrived so well in its new surroundings that the sugar industry spread rapidly to Cuba, Mexico, Brazil, and other provinces of the New World. In Louisiana, several unsuccessful attempts were made to introduce cane culture, but it was not until 1794 (three centuries after the first cane was brought over by Columbus) that the industry was established on a paying basis.

The processes of manufacture in the beginning were very primitive, and yet the essential stages of the process were the same as now; first came the crushing of the stalks and expression of the juice; second, the evaporation of this juice; and third, the crystallization and separation of the sugar. In all three of these stages the improvements during the last one hundred years have been greater than in all previous time, the great reason for which is that it is only about one hundred years ago that the steam engine was introduced into sugar manufacture.

After visiting a large modern sugar factory with its enormous steam-driven machinery, it is difficult for us to imagine how they secured power, previous to Watt's invention. In windy localities

they often made use of wind-mills, and this source of power is still largely utilized in Barbados. Where water power was available the crushing of the cane was done by water wheels. Fig. 1 is an old illustration of sugar manufacture, as it was carried out in Sicily about 1570. The picture shows in detail all the processes of manufacture; the stalks of cane were brought in from the fields on mules, were chopped into small pieces and carried in

FIG. 1. PRIMITIVE SUGAR FACTORY, SICILY.

baskets to a hopper, where they passed to a crusher driven by a water wheel. The crushed cane was squeezed in a screw press operated by man-power. The cane juice was then evaporated in a series of large kettles over the open fire; the thick mass of crystals which resulted was finally poured into conical moulds, where it solidified upon cooling. The loaves of raw sugar thus obtained were packed in bags and exported for refining.

Very similar to this were the early processes of sugar manufacture in the Western Hemisphere. Fig. 2 illustrates sugar manufacture, as carried out about 1630 in Brazil, when it was owned by the Dutch. In the distance is a sugar factory operated by water power. In the foreground is a stone mill driven by man-power; this is probably the oldest form of cane mill. The stalks were crushed between the heavy stone roller and the hard floor, the juice then being scooped up in pans and evaporated in kettles. The resulting mass of crystals was ladled into pots which were

then conveyed by natives to a cool place, where the sugar was allowed to harden.

Another old Dutch print of about the same time shows the interior of a sugar factory operated by water power (Fig. 3). The three vertical rollers for crushing the cane, and the method of transmitting power from the large water wheel will be noticed. In the foreground the operations of evaporating and filling the

FIG. 2. PRIMITIVE SUGAR FACTORY, BRAZIL.

sugar moulds are shown. In the background is a second cane mill worked by oxen, this mill also consisting of three vertical rollers. In some of these ox-driven mills the number of sweeps was increased to four or eight, so that several teams of oxen could be used; the power of the mill could thus be multiplied considerably.

The raw sugar made by these early methods of manufacture varied greatly in quality. The methods of clarification, before the days of chemical control, were naturally crude. One of the earliest and most available materials for eliminating the impurities of the juice was wood ashes. Milk was used as a clarifying agent as early as 600 A. D. in Persia, and it is interesting to note that milk is sometimes used for this purpose today in making maple sugar. As experience widened it soon became evident, however, that lime was the best and cheapest clarifying agent, and caustic or hydrated lime, which was used in Egypt as early as 700 A. D., is still the substance most universally employed. The evaporation of the cane juice was performed in open kettles over the direct fire, which method is always attended by caramelization and darkening of the sugar.

The elimination of the mother liquor, or molasses, from the crystals of sugar was not attempted in many early processes of manufacture, just as is the case today in primitive countries. For example, the Philippine concrete sugar, made by evaporating the juice to a very thick magma, which, after hardening, is broken up,

FIG. 3. EARLY SUGAR FACTORY, BRAZIL.[4]

contains all the soluble impurities of the juice. The juice is sometimes evaporated only to a semi-solid consistency, as in the case of certain Jamaica sugars. Sometimes this semi-solid mass of crystals is poured into hogsheads having openings at the bottom for the drainage of the molasses. The residue of sugar in the cask, as made by this process, is usually termed *muscovado*.

In some raw sugar factories the semi-liquid mass of sugar crystals, or *masse cuite,* was poured into a conical mould having an opening at the point for the escape of molasses. The loaves of sugar thus made varied in color from yellow to nearly black. In some cases the loaves of raw sugar were whitened by packing them in wet clay. The clay absorbed the molasses by capillarity and left a loaf of sugar which was nearly white. It was recognized that the loss by this process, through solution of sugar, was considerable; nevertheless this crude method of refining was formerly quite common.

Most of the raw sugar made in tropical America during the early days was sent to Europe for refining. Before this time the

[4] From Reesse's "De Suikerhandel van Amsterdam."

refining monopoly of the Venetians had been broken, and had passed to Amsterdam, which held the supremacy in this branch of sugar manufacture for several centuries afterwards.

We come now to the birth of the modern sugar industry, which may be said to date from 1806, when Napoleon announced his famous blockade of the continent of Europe against England. While his famous edict failed in its main purpose, it had a great influence in other ways, for it stimulated manufacturing and the arts to an unprecedented degree. In order to relieve the hunger of the people for sugar, heroic efforts were made to devise a substitute. In some parts of Europe, as Bohemia, maple sugar was manufactured, but the yield was not sufficient to supply even local demands. The famous chemist, Proust, then devised a process for obtaining the crystallizable sugar, dextrose, from grape juice. Another chemist, Kirchhof, also invented a process at this time for manufacturing dextrose from starch, and efforts were begun to establish a new starch-sugar industry. Dextrose, however, lacked the sweetening power of sucrose, and the consumers of sugar refused to content themselves with such a substitute.

About 50 years before this a German chemist, Margraf, had succeeded in isolating sucrose from the juice of the beet. Another chemist, Achard, followed up this discovery and in 1800 built a small factory for obtaining beet sugar on a commercial scale. The new industry, however, did not prosper at first and it was not until some ten years later that improvements made in France showed possibilities of success. Napoleon at once ordered large tracts of land to be set aside for beet culture. Under his powerful patronage and the guidance of the best scientists of the time, several factories were erected and the new industry was soon established upon a prosperous basis.

The overthrow of Napoleon and the abolition of the blockade opened again the markets of Europe to the supplies of tropical cane sugar and it seemed for a long time as if the new beet sugar could not compete with cane sugar, the cheaper product of tropical slave labor. French statesmen, however, were far-sighted enough to protect the new industry with bounties and tariff regulations, so that the manufacture of beet sugar increased. The financial difficulties which the industry encountered stimulated greater im-

provements and economies in agriculture and manufacture. This policy, after 50 years, placed the beet-sugar industry far ahead of its rival. The cane-sugar industry, temporarily handicapped by the abolition of slavery, was in its turn forced to make improvements, and this it could do only by adopting the newer inventions and discoveries that had been worked out in beet-sugar manufacture. It is worth our while to mention a few of the most important improvements which have been made in sugar manufacture since the foundation of the beet-sugar industry.

The first improvement was the vacuum pan, invented by the English refiner, Howard, in 1813. Previous to that time, sugar juices had been boiled in open kettles at high temperature, with great losses of sugar by inversion and caramelization. By boiling the sugar solution in a closed apparatus, from which the air had been pumped, the temperature of evaporation was greatly reduced; losses from inversion and caramelization were prevented, and a much whiter sugar was obtained. The efficiency of the vacuum pan was afterwards increased by the addition of the condensing column, which was invented by Davis in 1829. The condensing column consists simply of an upright pipe, some 35 ft. or more in height. Cold water passing downward through the pipe condenses the vapors from the vacuum pan; this condensation, aided by the barometric weight of the water column produces a high degree of vacuum.

Another great invention, of about that time, was the multiple effect, devised by a native of New Orleans, Norbert Rillieux. He conceived the idea of evaporating sugar juice, not in one but in several vessels, and of so connecting these that the hot steam from the evaporating solution in the first effect boiled the solution in the second, and the steam from the second effect boiled the solution in the third, and so on. By increasing the vacuums in the effects as the heating power of the steam diminished, it was found possible to boil off the water in a number of vessels by the heat which was supplied to the first unit of the series. The original patent of Rillieux, No. 4879, Dec. 10, 1846, gives the following description: "A series of vacuum or partial-vacuum pans so combined together as to make use of vapor from the evaporation of the juice in the first to heat the juice in the second, and the vapor from this to heat

the juice in the third, which latter is in connection with a condenser, the pressure in each succeeding one being less." The original evaporator of Rillieux was a triple effect and this is now probably the most common form of multiple evaporator, although there are quadruple, quintuple and even sextuple effects. Where more than three effects are joined, the juice in the first unit is usually boiled under, or slightly above, atmospheric pressure, in order to supply sufficient heat for carrying through to the last member of the series.

In 1835 the great French physicist, Biot, invented the polariscope, and no single piece of laboratory apparatus has done more to advance the science of sugar manufacture. It was possible, now, to determine sugar quickly and accurately and the foundation stone of chemical control in sugar manufacture was thus laid. More than this, the polariscope made it possible to analyze quickly the sugar beets used for seed selection. By selecting for seed each year the beets of highest sugar content the sugar percentage of the beet has been raised from 8.8% in 1838 to 18.1% in 1908, or more than doubled.

In 1844 the centrifugal was invented by Schotler and now it became possible to eliminate the molasses from the magma of sugar crystals in a few minutes, whereas months were consumed by the old process of drainage. In 1853 the filter press was invented by Needham and it was possible now for the first time to filter off the impurities of the clarified juice with neatness and dispatch. It is thus seen that, within 20 years, four great epoch-making inventions were introduced into sugar manufacture: the multiple effect, the polariscope, the centrifugal, and the filter press.

The appliance that we think of as most peculiarly connected with beet-sugar manufacture, the diffusion battery, was of comparatively late origin and was not introduced until 1864, by Jules Robert. Previous to that time, the juice of the beets had been removed by pressing the ground pulp; the diffusion battery accomplished the extraction so much better and cheaper that its adoption became universal within a few years.

In 1884 Wulff perfected the crystallizer, a machine in which thick mixtures of sugar and molasses could be slowly rotated while cooling. The sugar crystals were in this way brought constantly

into contact with fresh portions of liquid and were thus built up at the expense of the sucrose dissolved in the molasses. Previous to this invention, crystallization took place by allowing the mixture of sugar and molasses to stand for weeks and months.

The abolition of slavery in the West Indies, Cuba, Louisiana, and other tropical sugar-producing countries, and the consequent loss of cheap labor, at first caused the cane sugar industry a serious setback. This loss was aggravated by the favoring bounties and protection which the beet-sugar industry received. In order to compete with its younger rival the cane-sugar industry found it necessary not only to avail itself of all the improvements which the beet-sugar industry had developed, but to strike out in new directions of its own.

The greatest loss in cane-sugar manufacture has always been the inability of the mills to express all of the sugar from the cane. Attempts to apply the diffusion process to the cane industry had to be abandoned, simply for the reason that the residue of cane fiber was left in so wet a condition that it could not be used for fuel. The lack of coal and cheap fuel in the tropics makes it necessary for the cane-sugar industry to depend upon the extracted fiber, or bagasse, for generating steam for engines and evaporators.

The two great improvements which the cane industry had to develop for itself were better bagasse burners and better mills, and these two appliances stand in most intimate relationship since the better the mills the drier and more combustible the bagasse. In the old days of weak mills, and before blowing engines were used, the bagasse was so moist that it had to be dried in the sun before it could be used for fuel; in case of rain it had to be raked under shelter and spread out again when conditions were favorable. This process is still followed in primitive countries. In the most modern factories the bagasse is transported by carriers directly from the mill to the boilers, where it is burned by a forced draught from blowing machines; the combustion is perfect and the supply of bagasse is sufficient to supply all the fuel for operating the factory.

In the improvement of sugar-cane mills a great amount of effort has been and is still being spent. The cane mill is one of the most fascinating of engineering problems and one which has exercised the ingenuity of the greatest inventors. Such men as Henry Besse-

mer, the inventor of Bessemer steel, and John Hyatt, the inventor of celluloid, have patented methods for crushing and grinding sugar cane. Without going into a description of the various inventions

FIG. 4. HARVESTING CANE IN CUBA.[5]

it need only be said that the employment of the steam engine and the hydraulic press has enabled inventors to increase the grinding capacity of cane mills many thousand fold beyond that of the old ox-driven machines, and with much more efficient extraction.

FIG. 5. LOADING CANE ON STEAM TRAINS.

Let us now follow hastily the course of sugar from the time it leaves the field until it is bagged for shipment, basing our observa-

[5] This and the following illustrations are from photographs by the American Photo Co., Havana, Cuba.

tions on modern Cuban practice. When the sugar cane has reached the proper stage of ripeness, which in Cuba occurs in

FIG. 6. YARD OF A CUBAN SUGAR FACTORY.

December, the operation of harvesting begins. The cane is cut entirely by hand, as shown in Fig. 4, this first step of the process

FIG. 7. DUMPING CANE AT FACTORY.

having undergone no real change since the industry began. Harvesting by hand is expensive, yet inventors have spent their lives

and fortunes in efforts to perfect a cane harvester. The great difficulty lies in the irregular growth of the cane, the stalks in some cases being so crowded and intertwined that the field is an impassable jungle. Consider also the mechanical complications of a machine to cut the cane close to the ground, strip the leaves, and clip off the green top, while wasting none of the valuable part of the stalk. Several inventors have almost solved this problem, and

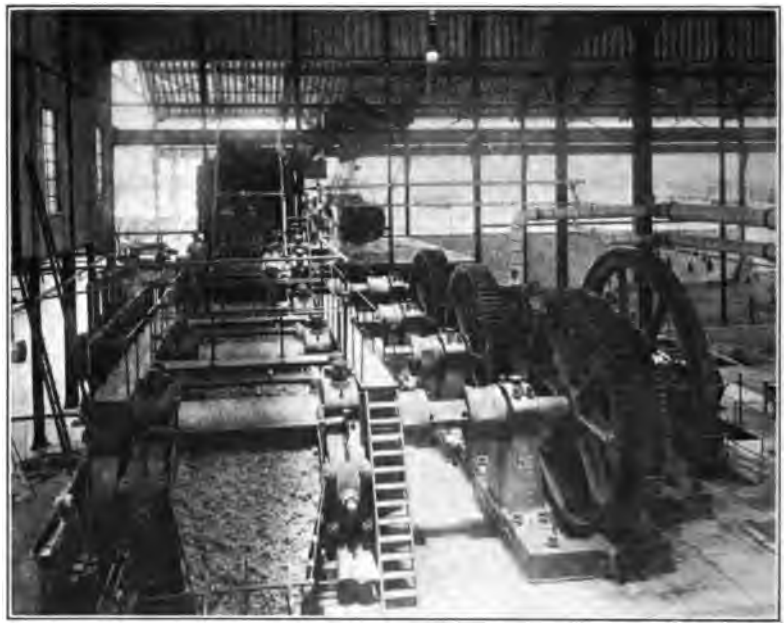


FIG. 8. ROLLER MILL.

the one who first succeeds will be enrolled among the great benefactors of the sugar-cane industry and, incidentally, will reap a considerable fortune.

The cane is next piled by hand upon carts and hauled to the factory. In the old days oxen or mules were the sole means of transportation between field and mill, and the area upon which a factory could draw for its supply of cane was limited by the hauling distance. Since the advent of the steam railroad, cane is now sometimes hauled 50 miles or more to the factory. The ox-teams deliver the cane to cars at the nearest siding, where it is transferred by hoists, as shown in Fig. 5. When enough cars are filled,

a train is made up and hauled to the factory. This method of transporting has vastly increased the cane areas upon which a factory may draw, and has rendered possible the erection of those large central establishments, some of which manufacture 50,000 or more tons of sugar in a season. One estate owns over 100 miles of railroad, and has some 1000 cars and 20 large locomotives. A train despatcher and force of signalmen are needed to keep trains moving with regularity.

FIG. 9. FILTER PRESSES.

The grounds before one of these factories resembles a large freight yard with its numerous tracks and switches (Fig. 6). As the trains of cane arrive, the cars are rapidly switched to the proper stations and are emptied by mechanical means to a large conveyor, as shown in Fig. 7. The conveyor carries the cane up a long incline and the mass of tangled stalks finally falls between two huge corrugated rollers forming the crusher. This reduces the stalks to an even blanket of pulp and squeezes out at the same time a large amount of juice which flows away at the bottom. (Fig. 8). From the crusher the cane passes to the first mill, which consists of three powerful rollers, two below and one above; it is next conveyed to a second and a third mill, and in some cases to fourth, fifth, and sixth sets of rollers; in the latter case there would be 18 rollers in

the milling plant in addition to the two rollers of the crusher. Between the mills a thin stream of water is sprayed on the cane which, being eliminated by the succeeding rollers, carries with it more and more of the residual sucrose. This process is called maceration and requires to be carefully controlled.

The pressure on the mills is gradually increased, as the cane advances, by powerful hydraulic presses; when the fiber leaves the

FIG. 10. INTERIOR OF SUGAR FACTORY, GENERAL VIEW.

final rollers it still contains between 40 and 50 percent. of moisture (usually nearer 50 percent.) with a small residue of unextracted sugar. The best mills extract over 95 percent. of the total sugar in the cane.

The expressed juice from the crusher and mills is then pumped into tanks, called defecators, where it is treated with milk of lime to neutralize its acidity; after this it is heated to boiling by steam coils. The lime combines with the organic acids of the juice to form insoluble compounds, and the heat coagulates the albuminous matter. A flocculent precipitate is formed, which partly rises to the surface to form a blanket of scum and partly settles to the

bottom as a sediment. After standing a short time the clear juice is drawn off, while the sediment and scums are passed through filter-presses and washed to remove adhering sugar, the runnings from the presses being then added to the main body of clarified juice. (Fig. 9.)

The clarified juice is next evaporated in the multiple effect to a syrup, which is then further concentrated in a vacuum pan to the point at which the sugar separates as a thick mass of crystals, the *masse-cuite*. The latter is then purged in the centrifugals, the sugar remaining behind and the molasses escaping.

The general lay-out of a modern sugar factory may be seen from Fig. 10, a view taken from the top of the cane mill. The bagasse from the last rollers falls upon a conveyor which carries it to the burners. The defecators for clarifying the juice are at the left. In the distance, on a high platform, is a triple effect and on the same level is the vacuum pan which is connected with a high condensing column. Underneath the vacuum pan are the crystallizers and centrifugals.

The molasses which escapes from the centrifugals still contains a considerable quantity of sucrose, and many processes have been devised to reduce this amount to the minimum. Owing to the accumulation of soluble impurities, such as invert sugar, salts, amids, gums, etc., in the molasses, and the high viscosity, the sucrose crystallizes out with much greater difficulty than from the original evaporated juice. In order to promote the crystallization, use is made of crystallizers (Fig. 11). The molasses is sometimes boiled down to a second crystallization and then emptied into the crystallizer, where it is slowly stirred by revolving arms. Or a certain amount of molasses may be drawn into the vacuum pan and boiled down with the *masse-cuite* from the pure juice, the whole being afterwards run into the crystallizer. Whatever the process, of which there are many modifications, the crystallizer simply facilitates the building up of crystals by keeping the particles of sugar always in contact with fresh portions of molasses. When the crystallization is finished, as is determined by analyzing a sample of the filtered mother liquor, the contents of the crystallizer are run off into centrifugals, the sugar purged, and the waste molasses pumped into tanks from which it is usually sent to dis-

tilleries. The utilization of molasses was described in the SCHOOL OF MINES QUARTERLY, July, 1913.

The sugar is dumped from the centrifugals into conveyors which carry it to chutes, where it is loaded into bags, and then placed in the warehouse ready for shipment. The Cuban bags of raw sugar weigh 325 lb. each, or about seven to the ton. The raw sugar, test-

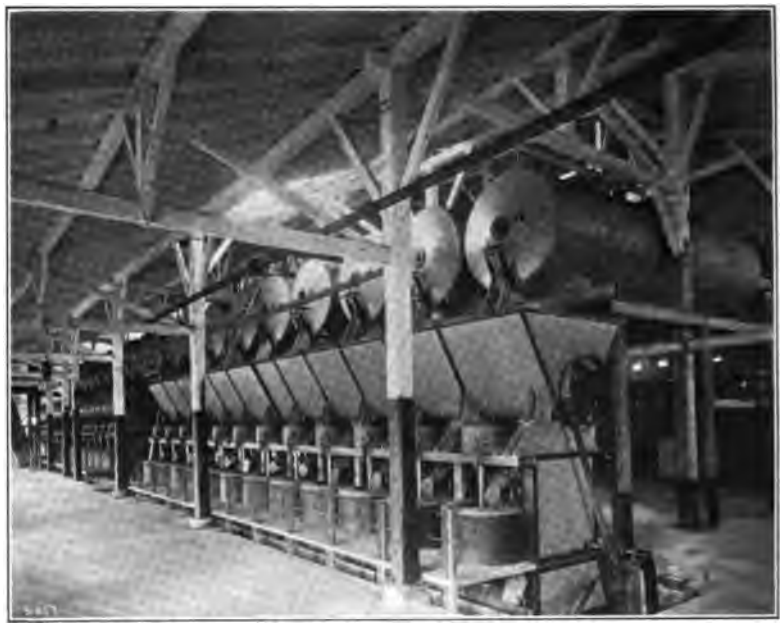


FIG. 11. BATTERY OF CRYSTALLIZERS.

ing about 96, is nearly all shipped to New York, Boston, Philadelphia, or New Orleans, where it is refined.

The great progress in sugar manufacture has been due not simply to the invention of better appliances in manufacture, but also, and in very large part, to the introduction of rigorous chemical control. The best appliances may do wasteful work unless constantly checked by strict chemical supervision. It is the duty of the sugar factory chemist to determine how much sugar enters the factory in the cane, and what percentage of this is obtained in the final product; to control the work of the mills by determining how much of the sugar in the cane is extracted and how much is lost in the bagasse; to control the work of clarification by determining the purity of

the juice before and after defecation; to control the work of evaporating and boiling by checking losses from inversion or entrainment; to control the work of the crystallizers by ascertaining that the final molasses has been reduced to the lowest possible sucrose content; and finally to control the quality of the raw sugar as to polarization, moisture, alkalinity, acidity, or any other factors which may affect the price or keeping quality of the product. Night and day, holidays and Sundays, the sugar factory chemists must be at their posts, for when the sugar campaign begins there is no let-up until the grinding season is finished. The moment a wrong turn occurs at any stage of the process, the fact must be quickly noted, lest large financial losses result.

The chemistry of sugar production has one other important side, which, unfortunately, is too much neglected. I refer to the chemical processes which take place where the cane is growing. We must never lose sight of the fact that the sugar which we eat is made in the field and not in the factory. If we determine all the factors that enter into the cost of sugar making, we shall find that about three-fourths of the expense is due to the agricultural operations of ploughing, planting, cultivating, and harvesting, and about one-fourth to the operations inside the factory. Strictly speaking, then, the agricultural side of sugar making should receive three-fourths of the attention bestowed by chemists and trained scientists. This has been largely true of the beet-sugar industry, a great part of the success of this branch of sugar making being due to the care given to chemical selection of seed and to other agricultural matters. The day is fast approaching when it will be equally true for the sugar-cane industry.

Unfortunately there still exists in some quarters a sort of contempt for that branch of chemistry which occupies itself with soils, fertilizers, tillage, irrigation, and the varied phenomena of plant life. This is a most narrow, mistaken point of view; the problems of agriculture are, in fact, the most important and most interesting in the whole field of applied chemistry, and the truly great chemists, such as Liebig and Humphry Davy, have recognized this. I predict that the opportunities of the chemist in the future will be found upon the agricultural side of sugar making, and that the ultimate goal in that field will be far more remunerative.

POROSITY OF BUILDING STONE.

BY D. G. CAMPBELL.*

The quality of a building stone depends upon a number of factors, of which the following are more directly influenced by the porosity or water contents: strength, color, mechanical disintegration by climatic agencies, and rate of chemical decay.

Porosity in itself has small effect in determining relative qualities of building stones. That is, stones may vary in percentage of pore space from 0.5 up to 20 or 25%, and yet, other things being equal, these extremes may not show great variation in strength. The important point in connection with porosity, however, is the *size* of the individual pores.

Sandstones are the least compact of the stones used largely for building; and their porosity ranges up to 28% of the total volume, which is near the theoretical maximum. Such rock, when exposed to water, will absorb large quantities, and is equally capable of releasing it by evaporation. Moreover, it is difficult completely to fill the pores of such a stone with water. Stones of which the pores are very fine are slow to give up their contained water; if this be then expanded by frost, such stone is gradually weakened and disintegrated. It is by reason of this fact that sandstones may be quarried and laid in freezing weather without injury, whereas fine-grained stones are likely to be seriously injured by such treatment.

Limestones and marbles have much less pore space than sandstones, ranging from 1 up to as much as 10%; while in granite the pore space is less than 1%. In these stones, the pores are capillary or sub-capillary in size. Hence, such stones absorb but little water, and absorb it slowly; once in, it is equally hard to get out. When such a stone, saturated with water, is exposed to a hard frost, freezing expands the pores, and by breaking the union of the interlocked grains weakens the structure. Stones of such fine-pored character are injured by being quarried in cold weather, for the small percentage of "residual water" cannot then escape readily, and may repeatedly freeze and thaw in the stone, before evaporating, thus increasing the destructive effect.

* E. M., Columbia University, 1914.

This distinction applies only to true porosity; for if a stone be laminated, water filling the spaces between the bedding planes may do a great deal of damage. Hence the rapid disintegration of inferior, shaly sandstones under severe climatic conditions.

If limestone and marble be thoroughly seasoned before being used, their small ratio of porosity, and fine pores, are great advantages, contributing much to their durability (*Merrill*). This is because the sub-capillary pores absorb water with extreme slowness and difficulty. Hence, it would seem inadvisable to employ marble or compact limestone where it would be exposed to dampness combined with extremes of temperature. The following table (*Buckley*) gives the ranges in loss of strength suffered by various samples of building stones due to alternations of freezing and thawing for 35 days:

LOSS OF STRENGTH BY FREEZING AND THAWING.

Rock	Orig. Strength Lb. per Sq. In.	Loss of Strength Lb. per Sq. In.	Loss, %
Granite	24,300	8,210	32
"	34,600	2,800	8
Limestone	30,680	13,675	44
"	8,100	570	7
Sandstone	4,170	1,950	46
"	5,330	930	17

LIFE OF BUILDING STONE. (*Julien*).

Coarse brownstone	5 to	15	years
Fine laminated brownstone	20 "	50	"
Coarse fossiliferous limestone	20 "	40	"
Coarse dolomitic marble		40	"
Fine-grained marble	50 "	100	"
Granite	75 "	200	"
Quartzite	75 "	200	"

The color of a building stone may be due to one or all of three factors: inherent color of the minerals composing the rock; material that acts as a binder to hold the rock particles together; foreign matter and impurities. As examples of the first may be mentioned granites, gneisses, diorites, and the igneous rocks in general. In the second category come sandstones mainly, such as brownstone and red sandstones. In this case the cement that holds the sand particles together is an iron oxide. In the third group

come sandstones containing carbonaceous material, such as bluestone and the like; also igneous and metamorphic rocks, granite, limestone, and marble, containing small but noticeable amounts of iron carbonate or sulphides.

In the majority of the uses to which building stone is put, its color, and especially a small variation of color, is of slight importance. In factories and business blocks, breakwaters and retaining walls, for street paving and similar uses, color is immaterial. In ornamental buildings and residences, however, or for decorative and artistic uses, the permanence of color, and its uniformity, is of considerable importance. These features are largely influenced by the porosity of the stone, and the amount of water which, percolating through it, is able to dissolve mechanically or change chemically the color-producing ingredients. In the first class of rocks named above, change of color is effected only by alteration of the original minerals; this change may be complete after the lapse of long periods of time, but does not take place to any great extent in the ordinary life of a structure or piece of ornamental work.

In rocks of which the coloring is due to, or affected by, foreign matter and impurities, change of color or bleaching is accelerated by dampness and water content. The sedimentaries, sandstone for instance, frequently contain much carbonaceous material, which produces blue, brown, buff, cream, and other tints. These may fade or be washed out by percolating water. This change is, however, fairly uniform, usually, and is not serious enough to depreciate materially the value of the stone.

With such impurities as carbonate and sulphides of iron, the changes that occur are much more marked and objectionable. These impurities are gradually oxidized and deposited on the surface as irregular brown blotches, or as long dripping stains. Such result may be caused by gradual percolation of iron impurities in the cement and mortar used in construction, or in the material of the backwall. This objectionable condition is most frequently met in limestones and some marbles, occasionally in granite; it greatly reduces the value, if it does not completely prohibit a stone so affected from being used for ornamental purposes where it is exposed to moisture.

In such rocks as red sandstones and brownstone, there is much

iron present in the form of oxide, serving as a cement to bind the particles of sand together. In this case no appreciable alteration of color is to be feared.

Besides the staining or bleaching produced by the oxidation of carbonate and sulphides of iron, a serious chemical effect is sometimes noted. This is due to the action of sulphurous and sulphuric acids released by this decomposition, which dissolve calcium carbonate, and deposit an incrustation of calcium sulphate on the surface of the stone. If the quantity of such impurities be large, this may be a source of serious weakening. Artificial stones and concretes have been made from rock and slags carrying a large percentage of iron, and they were either seriously decomposed or completely disintegrated within a few years.

Again, when a stone is subject to the action of running water, or water under pressure, or especially both together, the calcium carbonate contents of the stone must be kept low. Water containing even slight amounts of carbon dioxide is an excellent solvent for that mineral, and not only wears it away on the surface, but, seeping through, is likely to honey-comb it so as to render it useless. An instance is noted where, in an English aqueduct, limestone was used in the construction, and in a few years the leakage through honey-combing had assumed serious proportions. Rocks composed of or bound together by siliceous material are not noticeably affected this way, as silica is insoluble in ordinary surface water.

The minerals composing the igneous rocks, as granite and rhyolite, are also subject to alteration and decay, but this proceeds so slowly that it is seldom apparent in the ordinary lifetime of a structure. Quartz and feldspar are the principal minerals. The former does not change at all, the latter very slowly under the influence of weathering. The accessory minerals, mica, pyroxene, amphibole, and olivine sometimes occur in considerable proportions. These decay by oxidation and hydration much more rapidly and, especially if rich in iron, may cause trouble. If the stone contain many minute fractures, this weakening may be intensified, due to the fact that the products of alteration, serpentine, talc, chlorite, and the like, forming in thin, slippery layers and scales, make an excellent lubricant to aid any severe stress or shock in rupturing the stone. For this reason, stones rich in crystal micas, amphiboles,

and pyroxenes, greenstone for instance, are usually viewed with disfavor.

To summarize the foregoing, it may be said that:

(1) The strongest and most enduring rocks have the least porosity; granites and gneisses less than 1%, limestones up to 10%, sandstones up to 20%.*

(2) Of unseasoned stones, those having large pores, as the sandstones, are less likely to be injured by freezing than those having sub-capillary pores.

(3) Water seeping through porous rocks usually bleaches and carries away color-forming impurities, and these may be deposited on the surface in the form of incrustations and stains.

(4) A porous stone possessing calcareous ingredients, on exposure to running water or to water under pressure, is likely soon to become honey-combed and to disintegrate.

(5) The accessory minerals of igneous rocks are also subject to slow alteration by oxidation and hydration, and if present in large quantities, may prove a source of weakness.

* This is ascribed to the comparative value of the binding material, silica, calcium carbonate, and iron oxide, respectively, the relative value of these as binding agents being (*Buckley*) in the order named.

BOOK REVIEWS.

Chemical Annual. Edited by JOHN C. OLSEN and ALFRED MELHADO. Third issue. A Hand-Book of Useful Data for Analytical, Manufacturing, and Investigating Chemists, and Chemical Students. Cloth; 5 x 7½ in.; xiv + 663 pp., 114 tables of chemical, physical, and mathematical data. D. Van Nostrand Co., New York. 1914. Price $2.50 net.

This book supplies chemist, chemical engineer, physicist, and research metallurgist with a mass of reliable data, gathered and edited in such form as to enable ready reference. Compared with former issues, a number of new tables have been added, and the tables of the former edition have been revised, enlarged, and the most recent data incorporated. Addition of the chapter on Stoichiometry embodies definitions of the fundamental units, descriptions of methods determining specific gravities of liquids and solids, gas calculations, and problems such as the investigating chemist and technologist confronts from time to time.

One of the commendable features of the book is the high grade of paper used in its making, and the excellent material of the binding. Even though the book contains 685 pages, it is no thicker than the ordinarily published text book, containing half this number of pages.

Section I, pages 1 to 47, includes: International atomic weights of 1913; Mendeleeff's periodic system of the elements; specific gravity of gases; physical constants of the elements; gravimetric factors of compounds and their logarithms; factors for calculating indirect gravimetric analyses; the molecular and the atomic weights of compounds and elements, with their weight number and logarithm.

Section II, pages 51 to 69, contains tables used in the calculation of volumetric analyses, such as: basicity of acids with various indicators; values of normal solutions; physical and chemical constants of oils, fats, and waxes; temperature corrections for refractive indices and for specific gravity of oils.

Section III, pages 70 to 97, gives tables useful in the calculation of gas analyses, such as: reduction of gas volumes to normal temperature and pressure; corrections for barometric readings of temperature; coefficients of expansion of gases; solubility of gases in water; density of nitrogen and carbon monoxide; logarithms of numbers.

Section IV, pages 99 to 378, embodies physical and chemical constants of chemical compounds (inorganic, organic, alkaloids, and essential oils); and the melting points and the compositions of fusible alloys.

Section V, pages 379 to 468, incorporates: specific gravity tables of acids, alkalies, alcohols, glycerine, and solutions of the commoner salts; vapor tensions of water and mercury at different temperatures and pressures.

Section VI, pages 469 to 480, contains tables of equivalent metric weights and measures, to those of the United States and the British standards.

Section VII, pages 481 to 511, includes thermochemical tables of the

heat of formation and the heat of solution of the principal compounds, the heat of combustion of various substances (gases, liquids, and solids), and of coals, woods and the commercial liquid and gaseous fuels.

Section VIII, pages 515 to 570, is given entirely to stoichiometry, and is a commendable feature of the book, as it contains the definitions of the fundamental units of length, mass, weight, pressure, and expansion. This is followed by calculations, methods of determining specific gravities of different materials, and 58 typical problems. The thermometer and the barometer are next considered, giving the fundamental principles on which they operate, and 37 problems of gas calculations. Methods of mixing different materials, and of diluting solutions, so as to obtain a desired percentage content of a mutual component, are discussed, and a number of problems are given which involve the use of the tables given in the book. In all, there are 143 typical problems.

Section IX, pages 571 to 663, is a list of the more important scientific and technical books which have been published since July, 1909.

UNIVERSITY NOTES.

Semi-Centennial Celebration.—A full report of the proceedings in celebration of the fiftieth anniversary of the founding of the School of Mines will be given in the July, 1914, issue, to appear shortly.

Department of Mining.— At the request of the United States Bureau of Mines, a section in one of the rooms in the mining laboratory has been assigned to a representative of the Bureau, Mr. W. E. Gibbs, who has equipped it as a workshop and, with an assistant, is conducting experiments looking towards the improvement of the oxygen helmets so largely used in rescue work and fire fighting in coal mines. The automatic valves hitherto employed have proved to be both wasteful of oxygen, and sometimes uncertain in operation, especially when operated by an imperfectly trained worker, under stress of excitement, and the number of fatalities due to this cause has been alarming. An improved form of valve already developed by the Bureau's representative promises a satisfactory solution of these defects.

The larger part of the mining departmental library has been moved into a new and larger room on the third floor, where it has been combined with that of the Department of Metallurgy, thus forming an extensive collection of reference books, to be known as the Library of the School of Mines. It will be in charge of a permanent assistant from the staff of the general library. All of the catalogues, and some of the books most frequently consulted by the senior students in mining have been retained in the mining drafting room.

Professor Munroe, head of the department, on the urgent advice of his physicians, was persuaded to take a rest from his University work at the middle of February. On March 31 he had so far recovered from his illness as to be able to start for Europe with Mrs. Munroe. During his absence, his lecture courses have been divided among other members of the department. Professor Munroe expects to return in time to resume all his University work in September.

The only recent addition to the laboratory equipment is an agitator for conducting experiments on the flotation of ores, the gift of Mr. James M. Hyde. The Deister Concentrator Company has promised the gift of one of their latest sand concentrators. A valuable addition to the museum collection was received from the DuPont Powder Company, comprising dummy samples of a large variety of their explosives, fuses, detonators, etc.

The department has recently had the advantage of several special lectures from practicing engineers, notably one by Mr. Adolph Lewisohn on "Mining as a Business"; Mr. H. W. DuBois, on "Detection of Mine Salting"; Mr. N. B. Knox, '97 S. of M., on "Prospecting and Developing Gold Placer Deposits."

The Department has recently gained the privilege of using an abandoned mine at Roxbury Station, Conn., about 15 miles from Camp Columbia, at Morris. The property was first opened as a lead-silver mine about 150 years ago; it then entered a financially disastrous career as

an iron mine, and a large tonnage of carbonate ore was mined, and was smelted on the premises. The mine has now been idle for about 50 years, and it is to the courtesy of its owner, Mr. A. L. Hodge, that the School of Mines owes its opportunity to use the mine at the nominal rental of $1 per year. The primary object of securing the mine is to provide a suitable, permanent, and convenient place in which to conduct classes in mine surveying alone. No idea has been entertained of giving instruction in the practical details of mining, since for that work other and better arrangements are in force. Incidental to the process of clearing out the refuse in the mine and making it safe for students, Professor Munroe intends to conduct experiments on certain details of mine operation, but not as a course of instruction. The mine is opened by several self-draining levels, connected by shafts and winzes, and affords an admirable opportunity for the study of surveying. At least two years will be required to put the mine in shape, drawing only on the regular departmental appropriation. Owing to a generous gift of $1000 from Dr. James Douglas, it has been possible to make an immediate beginning.

Mechanical Engineering Society.— The meeting of Feb. 19, 1914, was distinctly a student meeting. H. F. Allen, '15, gave an account of his summer experiences in the Cooke works of the American Locomotive Co., at Paterson, N. J. He described the layout of the plant, the work produced, and the methods and systems employed by the company. R. P. Piperoux, '14, gave an interesting talk on the power plant of the French liner "La France." He described the engine room in detail, showing the arrangement of equipment, methods of handling coal, ashes, and water, and the systems of control. In concluding, he gave many interesting figures concerning the capacities and consumptions of the various units. The meeting then adjourned to the Commons, where refreshments were served.

At the meeting of Mar. 19, "Target Practice" was the subject of an address by Lieut. B. R. Ware, U. S. N. He first pointed out the importance of target practice, citing how superior marksmanship in the Spanish-American and Russo-Japanese wars was a potent factor in the victories. He then explained the method of range finding, the extensive systems of communication within a ship, and the control and firing of big guns. As an illustration of the damage wrought by the huge shells, and the accuracy of the gunners, Lieut. Ware told of the target practice on the old "Texas," where conditions were made to simulate actual battle conditions as nearly as possible. General discussion followed.

Highway Engineering.— Recent lectures in the graduate course in highway engineering included the following:

Feb. 28, 1914, Major W. W. Crosby, Chief Engineer Maryland Geological and Economic Survey, "Value of Cost Data in Highway Engineering."

Mar. 2, Prof. J. Ansel Brooks, of Brown University, "Principles of Efficiency Engineering Applied to Highway Engineering."

Mar. 9, Nelson P. Lewis, Chief Engineer, Board of Estimate and

Apportionment of New York City, "Administration of Municipal Public Works."

Mar. 16, C. N. Forrest, Chief Chemist, Barber Asphalt Paving Co., "Essential Physical and Chemical Properties of Creosote for Wood Blocks."

Mar. 19, John A. Bensel, New York State Engineer, "Relative Cost of Transportation by Waterways, Railways, and Highways."

The following notes, describing the library of highway engineering at Columbia University, were prepared by Miss Emma D. Lee, librarian, and constitute a part of the 1914 *Proceedings* of the National Highways Association:

To answer the needs of the highway engineer and to give him opportunities for original and concentrated research work, through the efforts of Charles Henry Davis, President of the National Highways Association, a library of highway engineering has been founded. This library is maintained in connection with the graduate course in highway engineering at Columbia University, and is the most complete collection of works on highway engineering and allied subjects in this country.

The library contains bound volumes, manuscripts, pamphlets, reports, specifications, maps, drawings, blue-prints, and the latest trade catalogs describing machinery and materials used in highway engineering throughout the world. Town, municipal, county, park, state, and government reports and specifications form a very valuable part of the library. In addition to works pertaining essentially to highway engineering, there are many volumes on allied subjects, such as chemistry, physics, geology, town planning, civic improvement, law, finance, scientific management, civil, and mechanical engineering. The rare books include treatises written in French, German, and English, dating as early as 1720, and including the first editions of the works of John Loudon McAdam.

Over 70 periodicals are subscribed to, including French, German, English, and Canadian journals. As a guide and aid in research work, all periodicals are abstracted and indexed on cards. In all technical literature, the latest information being none too new, it is the periodicals which usually contain the most valuable and recent data. Each abstract card contains the subject of the article, the title and author, the pages and columns of the periodicals in which it appears, a brief abstract, and a symbol indicating its value from the standpoint of the highway engineer. Often sufficient information is given on the card so that no further research is necessary. This file supplements the printed engineering indexes, the scope of which is necessarily too broad to allow of extensive indexing of any one subdivision of engineering, such as roads and pavements.

All monographs, pamphlets, specifications, and paper-bound reports are bound in numbered manila folders, and filed in a series of vertical cabinets of different sizes. The material contained in the files is indexed in three card catalogs covering authors, titles, and subject matter, respectively.

Many engineers have already availed themselves of the opportunity to carry on extensive research, and it is hoped that in the near future highway officials, engineers, contractors and all interested in any problem in highway engineering will feel free to consult and make use of this special library.

ALUMNI NOTES.

1875. Charles M. Rolker, E.M., announces removal of his office to 59a, London Wall, London, E. C.

1885. Joseph Struthers, Ph.D., has been made a vice-president of Johnson Electric Smelting, 18 E. 41st St., New York. The experimental plant of the company for electric smelting of mixed ores is at Hartford, Conn.

1886. Arthur W. Jenks, E.M., returned to New York in April, 1914, after having been for five years in charge of gold mines in northwestern Argentina.

1889. Percy L. Fearn, E.M., has returned from Costa Rica, where he had been consulting engineer for the Abangarez Gold Fields.

1893. Frederic S. Hyde, Ph.B., is author of a book, "Solvents, Oils, Gums, Waxes, and Allied Substances," published by D. Van Nostrand Co., as a condensed manual for factory chemists. Address, 215 Schermerhorn St., Brooklyn, N. Y.

1895. Henry Kraemer, Ph.B., was elected president of the Philadelphia Alumni Association of Columbia University.

1898. Juan P. Ros, E.M., is chief engineer of sewers in the City of Cienfuegos, Cuba. He has previously been chief engineer of the Western Mining Region, of Cuba.

1898. Henry Krumb, E.M., is with the Gunn-Thompson Co., Salt Lake City.

1900. Benjamin Magnus, E.E., general manager of the Mt. Morgan Gold Mining Co., Queensland, spent the summer of 1914 in New Guinea, inspecting mines of low-grade basic copper ore recently acquired by his company, and designing installation of trams and wharves.

1900. D. C. Reed, E.M., is chief engineer of the Cuzco-Santa Ana Railway of Peru. Address, 160 Avenida Tery, Barranco, Peru.

1900. N. B. Ambler, E.E., is superintendent of operation at the Niagara Falls generating and transformer station of the Toronto Power Co. Address, 68 N. Main St., Niagara Falls, Ontario.

1901. Walter C. Kretz, Mech. E., with J. A. Roebling's Sons, New York, was at Wellington, New Zealand, in May, 1914.

1901. Oscar W. Palmenberg, B.S., has recently been engaged in investigations of fuel and ash for the Solvay Co., Syracuse, for the American Strawboard Co., Norwich, Conn., and for the Brass & Foundry Works, at Ansonia, Conn. He was the author of a paper on the relation of ash composition to fusion temperature read before a recent meeting of the N. Y. Section of the Society of Chemical Industry.

1902. Julian Richmond, Mech. E., assistant engineer to the Board of Water Supply of New York City, spent the first part of 1914 in France, establishing the City of New York's exhibit at the Lyons International Urban Exhibition.

1902. Arthur Feust, E.M., has returned from Nicaragua, where he has been for about two years.

1903. E. R. Pembroke, E.M., and W. H. Hendrickson, E.M., are at Newhouse, Utah.

1903. F. S. Schmidt, E.M., of the Gunn-Thompson Co., Newhouse Bldg., Salt Lake City, has recently been busy with examination work.

1903. H. B. Barling, E.M., formerly manager of the Honduras Rosario Co., has returned to New York. Address, 11 Pine St.

1903. F. R. Rodriguez, E.M., is in Saltillo, Coahuilla, Mexico.

1903. S. F. Shaw, E.M., recently in charge of mines at Charcas, Mexico, has returned to New York. Address, 136 Liberty St.

1906. John B. Doughty, C.E., was married Jan 1, 1914, to Miss Anna A. Wright, at Oyster Bay, N. Y. Address, Jericho, N. Y.

1906. A. W. Evans, E.M., is manager of the Consolidated Gold Fields of New Zealand, at Reefton, New Zealand.

1907. Jesse J. MacDonald, who has been metallurgical engineer at the Magna plant of the Utah Copper Co., at Garfield, Utah, for the past three years, has resigned in order to attend to personal business in southern California. Address, Sierra Madre Club, Los Angeles, Cal.

1908. Oswald M. Lewyn, E.M., is superintendent of mines of the Braden Copper Co., Rancagua, Chile.

1908. H. R. Graham, E.M., and G. Helmrich, E.M., are on the staff of the Braden Copper Co., Rancagua, Chile.

1909. Wm. Fondiller, E.E., 2 Bank St., N. Y., is engaged in the physical laboratory of the engineering department of the Western Electric Co.

1909. L. E. Grant, E.M., is assistant to the manager of the Braden Copper Co., Rancagua, Chile.

1910. J. Tallant, E.M., is mine foreman with the Braden Copper Co., Rancagua, Chile.

1910. Victor Ziegler, A.M., recently professor of petrography and mineralogy in the South Dakota School of Mines, has been appointed assistant professor of the same subjects in the Colorado School of Mines. He is the author of numerous reports on the economic minerals of the Black Hills.

1910. Thomas K. Scott, E.M., formerly with the Inspiration Copper Co., is now with the Miami Copper Co., Miami, Ariz.

1910. A. C. Kaestner, C.E., is in the chief engineer's office of the U. S. Realty & Improvement Co., 111 Broadway, N. Y. City.

1911. John C. Hale, E.E., was married, March 28, 1914, to Miss Jessamine Martin. Address, 51 N. Washington St., Tarrytown, N. Y.

1911. Benjamin Liebowitz, E.E., was married, Feb. 12, 1914, to Miss Virginia Brand, New York City.

1910. L. A. Parsons, E.M., was married, June 24, 1914, to Miss Victoria Cross, at Stonehouse, Plymouth, Devonshire, England. Address, Copper Cliff, Ontario, Canada.

1911. Walter M. Stephen, E.M., has resigned a position on the forestry work of the Government to become assistant manager of the Cronk Mining Co., operating a gold quartz mine and cyanide plant at Martina, Missoula county, Mont.

1911. Robert L. Morrow, Mech E., is in the building and mainte-

nance department of the Western Electric Co., New York City. Address, 219 W. 70th St.

1911. J. R. Guiteras, E.M., is at Newhouse, Utah.

1911. E. G. Meyer, C.E., has established a contracting business for electrical and other engineering work in Newark, N.J. Was married, Feb. 11, 1914, to Miss Edith Glutting, of Newark.

1912. Hadji M. Der Garabedeian, C.E., recently assistant secretary of the American College at Constantinople, is now connected with a firm of constructing architects in that city.

1913. Jay L. Smith, C.E., is connected with the firm of Upton, Butler & Fishler, Newark, N. J., specialists in liability insurance. Was married, Feb. 3, 1914, to Miss G. Cunningham, of Upper Montclair, N. J.

William Bleecker Potter, A.B., E.M., 1869, died at his home in St. Louis, July 13, aged 68 years. He was born in Schenectady, N. Y., being a son of the late Bishop Potter of New York. For two years after graduation, he was assistant in the department of geology in the University, at the same time serving as assistant on the Ohio Geological Survey. In 1871 he was appointed professor of geology at Washington University, St. Louis, and retained his connection with the university for 22 years, until 1893. While holding his professorship he also served for two years as assistant on the Geological Survey of Missouri; as mining engineer of the Pilot Knob Iron Co.; as metallurgist of Vulcan Iron & Steel Works, St. Louis; as mining engineer of the Iron Mountain Co.; and as a member of the Board of Managers of the Missouri Geological Survey. In 1893 he resigned his professorship and since then has been consulting engineer and metallurgist. He founded the St. Louis Sampling & Testing Works, and was manager of those works up to the time of his death. Dr. Potter served as president of the St. Louis Engineers' Club in 1887 and as president of the American Institute of Mining Engineers in 1888; he was also a member of the Mining & Metallurgical Society of America. He was one of the best known mining engineers and metallurgists in the country, and his service as consulting engineer was often in request. In 1888 Dr. Potter married Agnes Kennett Farrar, of St. Louis, who survives him. He leaves also two daughters and two sons.

James Haviland Merritt, Ph.B., A.M., 1880, died in Brooklyn, N. Y., on March 17, 1914.

Alfred L. Beebe, Ph.B., 1880, died on June 26, at Mystic, Conn.

Sewall Truax, E.M., 1903, died at Highland Park, Ill., June 1. In 1906 he became manager of the Granadeña Mining Co., at Santa Barbara, Chihuahua, Mexico. In 1911 he conducted extensive experiments at Cañon City, Colo., in evolving a commercial process for vola-

tilizing zinc direct from slag and ores. For several years he has been a sufferer from rheumatism, and for the past two years had been unable to leave his bed. He leaves a wife and two children.

[redacted]

Hanford Curtis Adams, A.B., E.E., 1908, died in Jacksonville, Fla., on March 11, 1914. Mr. Adams was assistant in the department of electrical engineering of the University from 1908 to 1909.

[redacted]

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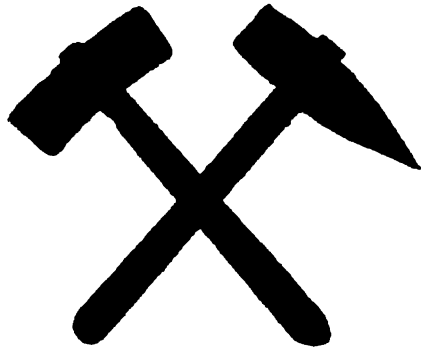
VOL. XXXV. No. 4. JULY, 1914.

THE

SCHOOL OF MINES QUARTERLY.

A JOURNAL OF APPLIED SCIENCE.

1864  1914

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NEW YORK CITY

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THOMAS EGLESTON.

FIRST ANNOUNCEMENT

OF THE

SCHOOL OF MINES

COLUMBIA COLLEGE

1863–64

Note.—This announcement was nearly a verbatim reproduction of an earlier "Plan for a School of Mines and Metallurgy," published by Professor Egleston, in March, 1863.

COMMITTEE

OF THE

TRUSTEES.

Names.	*Reſidences.*
WILLIAM BETTS, LL. D.,	122 Eaſt 30th.
EDWARD JONES,	75 Fifth Avenue.
GEORGE T. STRONG,	74 Eaſt 21ſt.
JOHN TORREY, M. D., LL. D.,	Columbia College.
LEWIS M. RUTHERFURD,	175 Second Avenue.

—o—

OFFICERS.

Names.	*Reſidences.*
CHARLES KING, LL. D., PRESIDENT,	Columbia College.
THOMAS EGLESTON, JR., A. M.,	10 Fifth Avenue,
Profeſſor of Mineralogy and Metallurgy.	

Other officers to be appointed before the opening of the School.

GENERAL STATEMENT.

THE Object of the SCHOOL OF MINES AND METALLURGY is to furniſh to the ſtudent the means of acquiring a thorough ſcientific and practical knowledge of thoſe branches of ſcience which ralate to mining and the working up of the mineral reſources of this country, and to ſupply to thoſe engaged in mining and metallurgical operations, perſons competent to take charge of new or old works and conduct them on thoroughly ſcientific principles.

The courſe of inſtruction will be ſuch that every pupil, in paſſing from one year to another, may acquire a thorough theoretical knowledge of each branch, of which he will be required to give evidence at the cloſe of the ſeſſion, by written and oral examinations. At the commencement of the following year he will be required to ſhow, from reports of works viſited, that he not only underſtands the theoretical principles of the ſubjects treated, but alſo their practical application; a point that will be inſiſted on with great rigor.

Students who wiſh to enter the School muſt not be leſs than ſixteen years of age; and they will be required to enter for the whole courſe of inſtruction, or for ſome ſpecific branch of it. It will be well for them to have a previous knowledge of Algebra and Geometry, and of the rudiments of Chemiſtry and Phyſics. They ſhould be able to execute a colored drawing, on two

planes of projection, of a model preſented to them.* If the ſtudent ſhould not have theſe qualifications it will be found to be a great impediment to his progreſs.

The method of inſtruction will be by lectures, given by the corps of Profeſſors, practice in the Chemical and Metallurgical Laboratories, propoſals and drawings for practice for the eſtabliſhment of metallurgical works and for mining, and reports of viſits to metallurgical and other works.

Lectures will be delivered on the following ſubjects:

Analytical Chemiſtry,
Metallurgy,
Mineralogy, including Lithology and the formation of Metallic veins.
Geology,
Palæontology,
Machines,
Mining,
Mining Legiſlation.

Inſtructions will be given in *Machine Drawing, Shades, and Shadows, French and German.*

The courſe of inſtruction will continue through three terms of ſix months each, commencing the 15th of November and cloſing the 15th of May with an examination on the ſtudies of the year.

Students of the ſecond and third years will be required to preſent themſelves at the School on the 1ſt

* Perſons wiſhing to enter the School, who are deficient in theſe branches, can have the requiſite inſtruction given them, on application at the School, before the cloſe of the ſeſſion.

of November to hand in their journals of travel and to work up their memoirs: theſe muſt be completed before they will be allowed to attend the lectures. The lectures will commence on the 15th of November, and will be delivered by the Profeſſors of each department; thoſe of Chemiſtry, Metallurgy, and Mineralogy, laſting through two years; Geology, Palæontology, Machines, Mining, and Mining Legiſlation, laſting each, one year.

The third year will be ſpent by the pupils in the practice of aſſaying ores and matallurgical products, which they will be required to do by the dry and wet way. A method of treatment will be required to be given for each ore or *matte* aſſayed; and in cafe the matallurgical ſpecimens examined ſhould be the reſult of any derangement or accident, ſuch as a ſlag containing too large a per centage of the metal, an opinion, in writing, will be required as to the beſt method of treating it. They will alſo be required to draw plans for metallurgical works and mining machinery; each plan to be accompanied by a memoir, giving the reaſons for its adoption, and the coſt, in detail, of its execution. Each pupil will thus make, during his third year, not leſs than ſix plans applicable to the different caſes he may meet with in practice.

Any pupil of the third year who has been proficient in any one branch, may, if he wiſh, devote part of his time to it, under the direction of the Profeſſor of that branch, and may be attached as an aſſiſtant to one of the laboratories; in which caſe he will not be ſubject to the ſame regulations as the other ſtudents, and a compenſation may be allowed him for his ſervices. This

proviſion is made with the view of ſupplying unuſual advantages to thoſe ſtudents who have proved themſelves worthy of it, and as an incentive to greater zeal in the proſecution of the ſtudies of the courſe; and this fact will be mentioned in his diploma.

The lectures will be:

FIRST YEAR.

CHEMISTRY.— Non-metallic elements, and alkalies.

METALLURGY.—Making of bricks, conſtruction of furnaces, and metallurgy of iron.

GEOLOGY.

MACHINES AND RESISTANCE OF MATERIALS.

MINERALOGY.—Cryſtallography, uſe of the blowpipe, and deſcription of minerals.

SECOND YEAR.

CHEMISTRY.— Alkaline earths, metals, and chemiſtry of building materials.

METALLURGY.—Copper, Lead, Silver, Zinc, Tin, Antimony, Biſmuth, Cobalt, Nickel, Gold, Platinum.

PALÆONTOLOGY.

MINING AND MECHANICAL PREPARATION OF MINERALS.

LITHOLOGY AND FORMATION OF METALLIC VEINS.

THIRD YEAR.

MINING LEGISLATION.

The exerciſes for practice will include

DRAWING.

Drawings of furnaces and machines relating to the working of metals, and to mining, with the details of the coſt of eſtabliſhment.

SURVEYS.

Surveys of metallurgical eſtabliſhments as well as ſurface and underground ſurveying.

CHEMISTRY.

Manipulations in the chemical laboratory. During the firſt half of the firſt year chemical preparations will be made in order to familiarize the ſtudent with the different methods which he will be obliged to uſe in analyſis. The laſt half of the firſt year and the whole of the ſecond will be devoted to chemical analyſis. A detailed report of each preparation and analyſis will be required to be given in writing by each pupil. The third year will be devoted to the practice of aſſaying ores.

MINERALOGY.

Manipulation of minerals, rocks, and metallurgical ſpecimens. The laſt half of the year, Mineralogical conferences will be held by the Profeſſor of Mineralogy, when the ſtudents will be required to determine minerals placed before them, either by their phyſical or blowpipe characters. Thorough inſtruction will be given in the uſe of the blowpipe.

One day in each week will be devoted to the examination of the pupils, and to the inſpection of their note books, which they will be required to keep with care.

The ſtudents will viſit, with one of the Profeſſors, the different machine ſhops and Metallurgical eſtabliſhments of the city and its environs, and will be required to write a report, which will be counted as equal to two weekly examinations in the account of their ſtanding.

Every year during the receſs the ſtudent will be expected to viſit mining and metallurgical eſtabliſhments, and hand in, on his return, a journal of his travels, and a memoir on ſome ſubject aſſigned to him. Theſe memoirs will be counted as equal to ſix weekly examinations. He will alſo be required to bring collections, illuſtrating his journal and memoir, which collections will be placed in the Muſeum, reſerved as a medium of exchange, or made uſe of in the laboratories.

For pupils who have been proficient, and who deſire to devote ſpecial attention to any one branch, application will be made for permiſſion to work in particular Mines or Manufactories. This will be done only as the higheſt reward of merit that the Inſtitution can give.

COLLECTIONS.

Collections will be made of

MINERALOGY, LITHOLOGY, AND METALLIC VEINS.

GEOLOGY AND PALÆONTOLOGY.

METALLURGY.—Specimens of Metallurgical products to illuſtrate the Metallurgical lectures and models or drawings of furnaces uſed in working the different ores.

MODELS OF MACHINES AND MINING TOOLS.

Each Profeſſor will have the charge of the collections belonging to his own department. The whole to be under the charge of a curator.

LIBRARY.

A Library relating to the different ſciences taught will be placed in the ſchool, to which the pupils will have acceſs during certain hours.

CATALOGUE OF THE
FIRST YEAR

OF THE

SCHOOL OF MINES

COLUMBIA COLLEGE

1864–65

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FREDERICK A. P. BARNARD, S. T. D., LL. D.	Columbia College.
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President.	
THOMAS EGLESTON, Jr., A. M., E. M.	10 Fifth Avenue.
Professor of Mineralogy and Metallurgy.	
FRANCIS L. VINTON, E. M.	5 Grace Court, Brooklyn Heights.
Professor of Mining Engineering.	
CHARLES F. CHANDLER, Ph. D.	246 E. 51st Street.
Professor of Chemistry.	
JOHN TORREY, M. D., LL. D.	Columbia College.
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Lecturer on General Chemistry.	
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Lecturer on Mining Surveying.	
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Lecturer on Mathematics.	
OGDEN N. ROOD, A. M.	Columbia College.
Lecturer on Mechanics and Physics.	
JULIUS MAIER, Ph. D.	Hoboken.
Assistant in Analytical Chemistry and Instructor in German.	
WILLIAM A. POTTER, A. B.	16 Gramercy Park.
Assistant in Analytical Chemistry.	
ALBERT HUNTINGTON CHESTER	
Assistant in Mineralogy.	
HENRY B. CORNWALL, A. B.	508 Seventh Av.
Assistant in General Chemistry.	

STUDENTS.

NAMES.	RESIDENCES.	CITY RESIDENCES.
John Magnus Adams, A. B.,	New York,	87 East 13th St.
Henry Baldwin,	"	48 East 25th and 70 Wall St.
William Packer Bellamy,	Brooklyn,	2 Grace Court.
Samuel Willard Bridgham, Jr.,	New York,	24 Waverley Place.
Francis G. Brown,	Tarrytown.	
Edward Stelle Brownson,	Brooklyn,	16 Sidney Place.
Douglass William Burnham,	New York,	128 Fifth Avenue.
Thomas Cooper Campbell,	"	112 Lexington Av.
John Henry Caswell,	"	842 Fifth Avenue.
John A. Church,	"	124 Lexington Av
George Hampton Coursen,	"	66 West 19th St.
Oliver Eaton Cromwell,	Rye.	
W. G. A. Drake,	New York,	2 Rutherford Pl.
William Stuart Duval,	Brooklyn,	8 Monroe Place.
Charles Butler Evarts,	New York,	7 West 14th St.
Jonathan Odell Fowler, Jr.,	"	59 East 23d Street.
Edward Everett Giddings,	Pierrepont Manor,	215 West 36th St.
Charles King Gracie,	New York,	74 Ninth Street.
John Louis Gross, Jr.,	"	12 East 17th Street.
Albert Ward Hale, A. M.,	"	17 East 31st Street.
Thomas Hays Harmer, A. B.,	"	47 East 37th Street.
Robert Hay,	"	105 Madison Av.
Frederick Erastus Hyde,	"	39 West 34th St.
Julian James,	Cold Spring,	46 West 39th St.
Frederic Rhinelander Jones,	New York,	14 West 23d Street.
Lewis H. Livingston, Jr.,	"	5 University Place
James B. Livingston,	"	5 " "
Edward Whittlesey Lowrey,	Southington, Ct.	176 E. 14th Street.
Ignatius Loynaz,	Cuba,	11 West 11th St.

NAMES.	RESIDENCES.	CITY RESIDENCES.
EDWARD JONES MALLETT,	New York,	139 Second Avenue.
SAMUEL HOLMES MEAD, JR.,	"	233 W. 34th Street.
HENRY A. MELLY,	"	63 St. Mark's Place.
L. HORATIO MITCHELL, C. E.,	Cambridge,	153 East 51st Street.
CHARLES ALLEN OGDEN,	Astoria.	
CLEMENT OGDEN,	"	
FREDERIC MILTON PETIT,	Moira,	215 West 36th Street.
J. FRED. PIERSON,	New York,	28 West 19th Street.
FREDERICK PRIME, JR.,	"	14 East 17th Street.
E. E. ROBERTS,	Hartford,	Everett House.
CLARENCE STEPHENS,	Brooklyn,	230 Washington Ave.
WILLIAM WEY TUTTLE,	New York,	118 Fifth Avenue.
DAVID VAN LENNEP,	"	170 West 21st Street.
SHIPMAN S. WETMORE,	Brooklyn.	
ROBERT C. MCILWAIN,		
SIDNEY TUTTLE,	New York.	
HENRY B. CORNWALL,	"	
ALBERT H. CHESTER,	Buffalo.	

Total 47

CALENDAR.

1864—NOV. 15.—FIRST SESSION BEGAN ON TUESDAY.
NOV. 24.—THANKSGIVING DAY.
DEC. 24.—CHRISTMAS VACATION BEGAN SATURDAY.
1865—JAN. 3.—CHRISTMAS VACATION ENDED TUESDAY.
MAY 12.—SESSION CLOSES.
MAY 18.—EXAMINATIONS BEGIN.
MAY 25.—EXAMINATIONS END.
MAY 26.—EXAMINATION OF CANDIDATES FOR ADMISSION.
NOV. 1.—SECOND AND THIRD YEAR STUDENTS RETURN.
NOV. 13-14.—EXAMINATION OF CANDIDATES FOR ADMISSION
NOV. 15.—SESSION BEGINS.

GENERAL STATEMENT.

THE object of the School of Mines is to furnish to the student the means of acquiring a thorough scientific and practical knowledge of those branches of science which relate to mining and the working up of the mineral resources of this country, and to supply to those engaged in mining and metallurgical operations, persons competent to take charge of new or old works and conduct them on thoroughly scientific principles.

The method of instruction will be lectures, given by the corps of Professors; practice in the Chemical and Metallurgical Laboratories; proposals and drawings for practice for the establishment of metallurgical works, and for mining; and reports of visits to metallurgical and other works.

Instruction will be given in the following subjects:

ANALYTICAL GEOMETRY,
DIFFERENTIAL AND INTEGRAL CALCULUS,
DESCRIPTIVE GEOMETRY,
MECHANICS,
PHYSICS,
INORGANIC CHEMISTRY,
ORGANIC CHEMISTRY,
STOCHIOMETRY,
ANALYTICAL CHEMISTRY,
METALLURGY,
ASSAYING,
MINERALOGY,
BOTANY,
GEOLOGY,
PALÆONTOLOGY,
MINING,
MACHINES,
MINING SURVEYING,
MACHINE AND MAP DRAWING.

The course of instruction will continue through three terms of six months each, commencing the 15th of November and closing the 15th of May, with an examination on the studies of the year.

The method of instruction will be such that every pupil, in passing from one year to another, may acquire a thorough theoretical knowledge of each branch, of which he will be required to give evidence at the close of the session, by written and oral examinations. At the commencement of the following year he will be required to show, from reports of works visited, that he not only understands the theoretical principles of the subjects treated, but also their practical application; a point that will be insisted on with great rigor.

REQUIREMENTS FOR ADMISSION.

Students who wish to enter the School must not be less than sixteen years of age.

Candidates who enter for a degree must pass a satisfactory examination in Arithmetic, Davies' Algebra, Legendre, and Plane Trigonometry, or their equivalent.

The examination for admission, will be held on

Persons who are not candidates for a degree may, by a special arrangement, pursue any of the branches taught in the school, without previous examination.

COURSE OF INSTRUCTION.

LECTURES.

The lectures will commence on the 15th of November, and will be delivered by the Professors of each department; those of Chemistry, Metallurgy, and Mineralogy, lasting through two years; Geology, Palæontology, Machines, Mining, and Mining Legislation, lasting each, one year.

FIRST YEAR.

Mathematics { Analytical Geometry, Diff. and Integ. Calculus.
Descriptive Geometry and Drawing.
Mechanics.
Mining Surveying.
Physics.
Inorganic Chemistry.
Stochiometry.
Analytical Chemistry.
Mineralogy.

SECOND YEAR.

Mineralogy.
Metallurgy.
Mining Engineering (Exploitation of Mines).
Analytical Chemistry.
Botany.
Geology.
Palæontology.
Organic Chemistry.

THIRD YEAR.

Mining Legislation.
Theory of Veins.

METALLURGY.
MINING ENGINEERING (Machines, Construction, &c.)
ANALYTICAL CHEMISTRY.
ASSAYING.

Candidates for the degree of Engineer of Mines will not be required to attend the lectures on Organic Chemistry, and those for the degree of Bachelor of Science need not attend the lectures on Mining Engineering.

TEXT-BOOKS.

Davies' Analytical Geometry.
Davies' Differential and Integral Calculus.
Davies' Descriptive Geometry.
Peck's Mechanics.
Silliman's Principles of Physics.
Fownes' Manual of Chemistry.
Cooke's Chemical Problems and Reactions.
Tuttle and Chandler's Qualitative Analysis.
Fresenius' Qualitative Analysis.
Fresenius' Quantitative Analysis.
Dana's Manual of Mineralogy.
Elderhorst's Blowpipe Analysis.
Dana's Manual of Geology.
Ahn's German Grammar.

EXERCISES FOR PRACTICE.

DRAWING.

The first and second year will be devoted to Machine drawing.

During the third year, students will be required to draw plans for metallurgical works and mining machinery; each plan to be accompanied by a memoir, giving the reasons for its adoption, and the cost, in detail, of its execution. Each pupil will thus make, during his third year, plans applicable to the different cases he may meet with in practice.

SURVEYING.

Surface and underground work.

CHEMISTRY.

Manipulations in the chemical laboratory. During the first year the students will be engaged in *qualitative* analysis. The second and third years will be devoted to *quantitative* analysis. A detailed report of each quantitative analysis will be required to be given in writing by each pupil.

ASSAYING.

The third year will be spent by the pupils in the practice of assaying ores and metallurgical products, which they will be required to do by the dry and wet way. A method of treatment will be required to be given for each ore or *matte* assayed; and in case the metallurgical specimens examined should be the result of any derangement or accident, such as a slag containing too large a percentage of the metal, an opinion, in writing, will be required as to the best method of treating it.

MINERALOGY.

Manipulation of Minerals, rocks, and metallurgical specimens. The last half of the year Mineralogical conferences will be held by the Professor of Mineralogy, when the students will be required to determine minerals placed before them, either by their physical or blowpipe characters. Thorough instruction will be given in Crystallography and the use of the blowpipe.

EXCURSIONS.

During the session, the students will visit, with one of the Professors, the different machine-shops and Metallurgical establishments of the city and its environs,

During the vacation every student will be expected to visit mining and metallurgical establishments, and hand in, on his return, a journal of his travels, and a memoir on some subject assigned to him. He will also be required to bring collections, illustrating his journal and memoir, which collections will be placed in the museum, reserved as a medium of exchange, or made use of in the laboratories.

For pupils who have been proficient, and who desire to devote special attention to any one branch, application will be made for permission to work in particular mines or manufactories. This will be done only as the highest reward of merit that the Institution can give.

Students of the second and third years will be required to present themselves at the School on the 1st of November, to hand in their journals of travel, and to work up their memoirs; these must be completed before they will be allowed to attend the lectures.

LIBRARY.

A Library and Reading-room relating to the different sciences taught are maintained by the school.

CABINETS.

Collections of specimens and models illustrating all the subjects taught in the school, are accessible to the students.

SCHOLARSHIPS.

A friend of the School has guaranteed the sum of two hundred dollars per annum for three years, to meet the expenses of instruction, text-books, etc., in the School of Mines, of one student from the Free Academy, to be selected by examination.

PRIZES.

Three Prizes, of one hundred dollars each, are offered by the same gentleman to students who shall pass a prize examination on the studies of the present year, satisfactory to the Faculty of the school.

Any pupil of the third year who has been specially proficient in any one branch, may, if he wish, devote part of his time to it, under the direction of the Professor of that branch, and may be attached as an assistant

to one of the laboratories; in which case he will not be subject to the same regulations as the other students. This provision is made with the view of supplying unusual advantages to those students who have proved themselves worthy of it, and as an incentive to greater zeal in the prosecution of the studies of the course; and this fact will be mentioned in his diploma. Candidates for prizes will be required to pass an examination in French and German.

DEGREES.

The degree of Engineer of Mines and Bachelor of Philosophy, will be conferred on those students who pass satisfactory examinations on either of the complete courses. Certificates of proficiency will be given to those who pass satisfactory examinations in any one branch. A special examination will be held for candidates for the degree of Doctor of Philosophy.

EXPENSES.

Candidates for a degree will be charged $160 per annum.

Students wishing to attend a single course of Lectures will be charged $30. Those who wish to devote the whole of their time to Chemistry and Assaying, will be charged $160 per annum for the use of the Laboratory. These fees will be payable, one-half in advance and one-half on the 1st of February. For any period less than one-half the session, the fee will be $100, in advance, except for candidates for degrees, for whom no deduction will be made. An extra charge will be made for instruction in French and German.

Students will be supplied with apparatus, and charged for what they fail to return in good order.

SCHEME OF LECTURES.

FOR FIRST YEAR STUDENTS.

Hours.	MONDAY.	TUESDAY.	WEDNESDAY.	THURSDAY.	FRIDAY.
9 to 10					
10 to 11	* Geometry. Prof. VAN AMRINGE.		Physics. Professor ROOD.	Physics. Professor ROOD.	Mathematics. Prof. VAN AMRINGE.
11 to 12		Physics. Professor ROOD.	Mathematics. Prof. VAN AMRINGE.		Mining Surveying. Professor PECK.
12 to 1	Physics. Professor ROOD.	Mathematics. Prof. VAN AMRINGE.			
1 to 2	Mineralogy, 1st Sec. Professor EGLESTON.	Mineralogy, 1st Sec. Professor EGLESTON.	Analytic'l Chemistry Prof. CHANDLER.		
2 to 3	Mineralogy, 2d Sec. Professor EGLESTON.	Mineralogy, 2d Sec. Professor EGLESTON.		Descriptive Geom'try Professor VINTON.	Descriptive Geom'try Professor VINTON.
3 to 4	Analytic'l Chemistry Prof. CHANDLER.		Inorganic Chemistry Professor JOY.	Stochiometry. Prof. CHANDLER.	Inorganic Chemistry Professor JOY.
4 to 5			‡ German. Dr. MAIER.		‡ German. Dr. MAIER.

FOR SECOND YEAR STUDENTS.

9 to 10					
10 to 11	Metallurgy Professor EGLESTON.	Metallurgy. Professor EGLESTON.			Organic Chemistry. Professor JOY.
11 to 12				Organic Chemistry. Professor JOY.	
12 to 1		Organic Chemistry. Professor JOY.	Geology. Prof. CHANDLER.	Geology. Prof. CHANDLER.	
1 to 2	Mineralogy, 1st Sec. Professor EGLESTON.	Mineralogy, 1st Sec. Professor EGLESTON.	Analytic'l Chemistry Prof. CHANDLER.	Mining Engineering. Professor VINTON.	Mining Engineering. Professor VINTON.
2 to 3	Mineralogy, 2d Sec. Professor EGLESTON.	Mineralogy, 2d Sec. Professor EGLESTON.			
3 to 4	Botany. Professor TORREY.	Botany. Professor TORREY.		Stochiometry. Prof. CHANDLER.	† Palæontology.
4 to 5			‡ German. Dr. MAIER.		‡ German. Dr. MAIER.

† FOR THIRD YEAR STUDENTS.

9 to 10					
10 to 11	Metallurgy. Professor EGLESTON.	Metallurgy. Professor EGLESTON.			
11 to 12					
12 to 1					
1 to 2			Mining Legislation.	Mining Engineering. Professor VINTON.	Mining Engineering. Professor VINTON.
2 to 3			Assaying. Prof. CHANDLER.		
3 to 4	Theory of Veins. Professor EGLESTON.	Theory of Veins. Professor EGLESTON.			
4 to 5			‡ German. Dr. MAIER.		‡ German. Dr. MAIER.

☞ Hours not occupied by Lectures are devoted to Laboratory Practice, under Prof. Chandler, Dr. Maier, and Mr. Potter, or Drawing, under Prof. Vinton.

* Not given after this Session. † Not given at present. ‡ Voluntary.

THE

SCHOOL OF MINES QUARTERLY

VOL. XXXV. JULY, 1914. No. 4.

SEMI-CENTENNIAL CELEBRATION.

GENERAL PROGRAMME.

Wednesday, May 27:

The Columbia Club held a smoker in the evening, to which all alumni were invited. Visiting alumni were invited to make the Club their headquarters during the entire celebration.

Thursday, May 28:

Registration in Earl Hall throughout the day.

5 P. M. Organ recital, St. Paul's Chapel.

9. Reception and dancing in the Gymnasium.

Friday, May 29:

10 A. M. Procession of alumni and faculty to the Gymnasium.

10:15. Convocation; addresses and conferring of honorary degrees. (Detailed report follows.)

1 P. M. Luncheon at the Commons.

3. First Chandler Lecture, by Dr. Leo H. Baekeland, Professor Chandler presiding; presentation of medal by President Butler. (Detailed report follows.)

4:30. Presentation of memorial tablet by Society of the Older Graduates. (Detailed report follows.)

4:30 to 6. Departmental gatherings, in the rooms of the several departments: Mining and Metallurgy, Civil Engineering, Electrical Engineering, Mechanical Engineering, Drafting, Chemistry, Geology, Mineralogy, Physics and Mechanics.

5. Organ recital, St. Paul's Chapel.

7:30. Anniversary dinner, Waldorf-Astoria Hotel. (Detailed report follows.)

Saturday, May 30:

10 A. M. Meeting of Electrical Engineers, in celebration of 25th anniversary of the establishment of the Department of Electrical Engineering.

3 P. M. Baseball game, Columbia Varsity vs. Chinese University of Hawaii, South Field.

GENERAL COMMITTEE

Benjamin B. Lawrence, Chairman	Frederick A. Goetze
William Barclay Parsons	Henry S. Munroe
William Fellowes Morgan	James F. Kemp
Thomas B. Stearns	R. E. Mayer
Daniel E. Moran	Louis D. Huntoon
Arthur S. Dwight	F. D. Fackenthal, Secretary

THOSE PRESENT.

Registration of visiting alumni was conducted at Earl Hall by a staff of interested undergraduates, under supervision of Louis D. Huntoon, '95. On registering, each alumnus received a ribbon badge bearing his name and class, and a supply of admission cards to convocation and luncheon, for the use of his friends. There were also distributed a facsimile reproduction of Thomas Egleston's "Original Plan for a School of Mines and Metallurgy in New York City"—March, 1863, "Reprinted in 1914 by C. F. Chandler in grateful remembrance of his first colleague at Columbia, the originator of the School of Mines"; also a facsimile reproduction of the First Announcement of the School of Mines, and of the first catalogue of the school, published for this occasion by the SCHOOL OF MINES QUARTERLY, on behalf of the Alumni Association of the School.

The following list is copied from the registration cards; it is probable that by no means all those who were present filed cards at the registration bureau.

Aaronson, I., '13
Abbey, Edward N., '08
Aceves, J. G., '10
Agramonte, Emilio, Jr., '86
Agramonte, Pedro H., '11
Aldridge, Walter H., '87
Alley, James B., '12
Alsberg, Julius, '01
Appleby, J. S., '88
Arendt, Morton, '98
Arnstein, Leonard, '07
Arrowsmith, R., '82
Atherton, Percy L.
Augustine, A. E., '13
Bach, M. G.
Balch, Samuel W., '83
Baldwin, Alfred F., '86
Bangser, William, '13
Banks, H. P., '11
Barlow, E. S., 1900
Barrett, Edgar G., '84
Banks, John H., '83
Bates, George B., '87
Baxter, Harold, '06
Bellinger, H. P., '87
Bellman, J. J., '97
Benedict, W. de L., '74
Benjamin, Marcus, '78
Bennett, G. L., '98
Berkey, Charles P.
Berry, W. G., '80
Bigelow, L. C., '03
Bird, J. T. Joseph, '83
Blaber, J. T., '10
Bliven, Edward M., '78
Blumenfeld, R., '11
Bodelson, O., '84
Bogert, M. T., '94
Boorman, K. M., '10
Bonner, Richard O., '09
Booth, J. Arthur, '78
Boring, William A., '89
Bowes, C. M., '10
Bradley, Alonzo B., '03
Bradley, George R., '05
Bradley, Seymour, '89
Bradley, Walter E. F., '05
Brettell, Clinton, '11
Bridges, C. B., '12
Briggs, Robert W., '11
Brinley, John R., '84
Brodie, Orrin L., '01
Bullard, Roger H., '07
Burgi, Herman, '13
Burns, A. L., '87
Burnside, C. H., '98
Busse, F. A., '03
Butcher, W. F., '12
Butler, Nathaniel, '80
Butler, Willard P., '78
Byron, Oscar, '14
Calvert, Robert, '14
Campbell, Donald G., '14
Campbell, William, '03
Cannon, H. G., '05

Carpenter, W. H.
Carpenter, W. M., '09
Carrerré, J. Maxwell, '83
Caruthers, A. W., '13
Casey, Edward P., '86
Cassidy, J. C., '14
Chandler, Charles F.
Channing, J. Parke, '83
Chun, Y. S., '14
Church, E. D., '87
Church, John A., '67
Clark, Josiah H., '97
Clarke, Henry J. Bowie, '02
Coan, Titus M., '61
Colas, Nicholas, '12
Cole, Howard T., '11
Compton, George B., '09
Cooke, Thomas F., '04
Cornell, B. C., '74
Cornell, R. T., '01
Cornwall, H. C., '79
Cornwall, H. F., '12
Cox, Wesley C., '13
Coykendall, Frederick, '95
Craft, La Vergne, '14
Crampton, H. E.
Crissey, C. P., '02
Crocker, Francis B., '82
Curtis, Gerald B., '06
Dana, R. K.
Daniels, M. H., '10
Danziger, J. L., '02
Davis, E. M., '80
De Ghueé, C. J.
Delgado, F. P., '01
Denton, F. W., '89
De Pew, P. H., '11
Deschere, Paul R., '11
Deutsch, Maurice, '06
Dickson, W. S., '12
Dieterlen, Charles T. E., '07
Dittenhoefer, Lester F., '03
Dittmer, Joseph C., '14
Doty, Archibald C., '07
Doud, Charles H., '01
Douglas, Archibald, '94
Douglas, John Sheafe, '90
Downe, W. F., '82
Drucker, S., '14
Dub, George D., '12
Duffie, Archibald D., '13
Dunn, Gano, '91
Durham, Henry W., '95
Duval, W. S., '68
Dwight, A. S., '85
Earle, Arthur W., '77
Eddison, W. Barton, '12
Egbert, Harry D., '10
Egbert, James C., '81
Egloff, G., '13
Ehrlich, J., '14
Eilers, Karl, '89
Elliott, Arthur H., '81
Elliott, William, '80
Elsasser, H. W., '14
Emanuel, L. V., '96
Engel, Louis G., '80
Englander, H., '11
Erhard, Georges, '79
Evyoub, Djevad, '15
Evans, Herbert W., '13
Faber, J. Eberhard, '78
Fabian, Francis G., '07
Fackenthal, Frank D., '06
Fearn, P. LeR., '89
Ferebee, S. H., '85
Ferguson, W. C., '87
Ferguson, W. E., '09
Feust, Arthur, '02
Fogel, William P., '11
Foster, Pell W., '83
Fox, Walter F., '14
Frambach, F. S., '11
Frank, Jerome W., '88
Freas, Thomas B.
Freehof, M. E., '14
Furniss, Clinton, '14
Gardner, F. Saltus, '14
Gartensteig, Charles, '95
Gately, W. A., '11
Geer, William M., '09
Gibson, Leon W., '09
Gildersleeve, A. C., '90
Gillie, George R., '09
Gillies, Edwin J., '82
Githens, Thomas F., '13
Goetschius, H. B., '76
Going, Charles B., '82
Golden, P. N., '01
Goldman, J. L., '14
Goldsmith, B. B., '87
Goodrich, R. R.
Graff, C. E., '85
Grabau, A. W.
Granger, Abbott D., '92
Grant, R. C., '09
Greene, W. A., '80
Greenleaf, James L., '80
Grossbaum, L., '13
Grunow, William R., '14
Hall, Henry L., '84
Hall, Randall C., '03
Hallock, Albert P., '80
Halsey, Charles B., '02
Hamann, A. M., '10
Hames, John P., '71
Hamlin, A. D. F.
Hardenberg, Daniel S., '04
Harmer, Thomas H., '64
Harrington, T. H., '89
Harris, Clarence P., '14
Harris, Edwin A., '89
Harris, Robert W., '14
Harrison, George I., '14
Hastings, J. B.
Hathaway, Henry S., '84
Hébert, Octave B., '88

Hehre, Frederick W., '08
Henry, A. D., '84
Herring, Albert C., '14
Hervey, William A., '93
Herzog, David S., '10
Hill, William, '82
Hirsh, Ralph T., '10
Hobart, Douglas R., '05
Hollmann, F. W., '05
Holt, Marmaduke B., '89
Holtzman, Paul J., '14
Houke, Theodore M., '80
Hooker, W. A., '66
Hooper, Frank C., '90
Hornbostel, H., '91
Hough, W. C., '81
Howe, Henry M.
Hoyt, G. P., '69
Huang, Chin Tao
Hudson, Darwin S., '01
Huntington, F. W., '85
Huntoon, Louis D., '95
Hutton, F. R., '76
Hutton, M. S., '05
Hyde, Frederick S., '93
Hyde, Henry St. J., '96
Hyman, W. M., '02
Ihlseng, Axel O., '77
Immerman, Harry T., '13
Irvine, F. B., '02
Iseman, P. R., '11
Israel, Albert H., '13
Ives, Francis L., '09
Jackson, Daniel D.
Jackson, Oswald, '92
Jacoby, Harold, '85
James, Alfred
James, Frederick W., '02
Janpen, Francis G., '81
Jaques, G. W., '08
Jaros, Alfred L., Jr., '11
Jeanneret, L. E., '11
Jenkins, Harold, '11
Jobbins, F. Hedley, '95
Joffe, Meyer, '94
Johnson, Douglas W., '03
Jones, Russell C., '05
Joseph, Leonard, '14
Judd, Edward K., '03
Kandel, Charles, '11
Kätz, Edgar J., '11
Kaufman, William, '14
Kemp, J. F., '84
Kemp, James T., '12
Kemp, William C. B., '72
Keppler, Emil A. C., '95
Kern, Edward F., '01
Keyser, C. J.
Kirschberg, M., '11
Klepetko, Frank, '80
Knapp, Charles, '87
Knox, Charles E., '92
Knox, Raymond C., '03
Kohlberg, H. S., '09
Kohler, L. Frank, '05
Kraemer, Henry, '95
Kraus, Arthur, '08
Kuang, Y. C.
Kraft, William J.
Kuhn, Samuel O., '11
Kuhnhardt, W. H., '80
Kunz, George F., '98
Lacy, F. Thurlow, '11
Lahey, R., '87
Laimbees, Jr., John, '83
Landman, Everett S., '14
Langmuir, A. C., '93
Langthorn, J. S., '91
Lapidus, A., '14
La Pierre, Lester S., '14
Lawrence, Benjamin B., '78
Le Boutillier, Clement L., '81
Leggett, Thomas H., '79
Leon, T. Carlos, '14
Levkowitz, Albert, '13
Lewinson, Leonard J., '04
Lighthipe, L. H., '63
Lighthipe, W. W., '98
Lindsley, George L., '06
Lindsley, Stuart, '70
Lipstate, W. A., '10
Livingston, Goodhue, '92
Lobo, G., '98
Loebenstein, Julian, '12
Longacre, O., Jr., '98
Lovejoy, John M., '12
Lovell, Earl B.
Lowenstein, G. A., '13
Lundborg, H. C., '14
Lunt, Horace F., '02
Lyman, Frank, '78
Luquer, Thatcher T. P., '89
Luquer, L. Mc I., '87
Lyon, C. S., '15
McClenahan, J. S., '14
McIlhiney, Parker C., '92
McIver, F. F., Jr., '13
McKeown, S. A., '11
McKinlay, William B., '95
McLoughlin, Frederic O. X., '13
Maas, Lester W., '12
MacCoull, Neil, '13
Machen, Henry B., '97
Maller, J. W., '10
Mampel, Charles J., '13
Mandle, H. H., '14
Marchmont, John H., '10
Marshall, F. B., '07
Marum, M. G., '11
Masters, H. K., '94
Mason, Frank L., '09
Masson, Henry J., '14
Mathews, John A., '95
Mayer, R. E., '79
Maynz, Theodore, '12

Meeks, R. V., 1900
Mein, M. W.
Meissner, Carl A., '80
Meissner, W. C., '00
Mendelsohn, Albert, '11
Mendelson, Walter, '79
Merritt, J. I., '06
Merz, Eugene, '92
Meserole, Walter M., '81
Messer, William Stuart, '05
Meylan, George L.
Miller, F., '11
Miller, James S., '14
Miller, Rudolph P., '88
Miller, S. O., '95
Millett, K. B., '07
Mitchell, Henry B., '97
Moeller, Edgar J., '95
Moldenke, Richard, '85
Monks, William D., '07
Montgomery, G. L., '11
Moore, Russell W., '83
Moran, Daniel E., '84
Morgan, T. C., '11
Morrill, William C., '99
Morris, Howard I., '05
Morse, Henry E., '14
Moses, Alfred J., '82
Mosley, Richard, '89
Mulford, Robert, '84
Müller, George, '87
Mullin, Francis
Munsell, C. E., '78
Myers, David M., '01
Neiman, Leo, '02
Newell, William, '05
Nichols, Harry P., '87
Nichols, Ralph, '77
Nighman, C. Edwin, '09
Nitchin, J. H., '70
Norris, Henry L.
Norris, R. V., '85
Norsworthy, L. D., '09
Nositzer, George, '14
Noyes, James A., '78
Oaks, F. J., Jr., '93
Ockert, Frederick W. '11
O'Connor, M. J., '81
O'Kane, N. G., '14
Olcott, E. E., '74
Oldright, G. L., '14
Osborn, S. Duffie, '79
Osterheld, T. W., '86
Page, George S., '85
Parker, Richard A., '78
Parker, Asa W., '99
Parr, Harry L., '02
Parsons, William B., '82
Peacock, W. T., '07
Pederson, Frederick M., '93
Peele, Robert, '83
Pell, F. Livingston, '95
Pellew, Charles E., '84
Peppmuller, Rudolph H., '95
Perkins, Thomas S., '88
Perrine, Harold, '07
Peters, George L., '11
Peters, William F., Jr., '11
Petty, John P., '85
Phipps, Frank H., '14
Pincus, S., '13
Pike, F. H.
Poole, A. M., '88
Powell, A. L., '10
Primelles, José, '87
Prosser, H. A., '96
Preston, G. B.
Provost, A. J., Jr., '89
Pulleyn, John W., '12
Purdon, John, '83
Rade, Henry S., '14
Ray, L. D., '82
Raymond, R. M., '89
Raynor, H. M., '59
Raynor, Russell, '89
Read, Thomas T., '02
Reed, Charles A., '83
Remington, H. W., '09
Renault, Georges, '83
Rhame, John F., '06
Rice, George S., '87
Richards, H., Jr., '03
Ricketts, P. de P., '71
Riesenberg, Felix, '11
Riley, Wells L., '11
Riordan, D. M.
Rogers, A. C., '04
Rogers, Augustus
Rolle, Sidney, '05
Ross, G. H., '10
Rothschild, F. W., '87
Saalberg, H. S., '14
Sachs, Albert P., '13
Sage, Edward E., '77
Sanguinetti, P. C., '03
Sawyer, Charles P., '81
Scheuch, W. A., '12
Schneider, A. F., '76
Schnitzer, William M., '95
Schreiber, Carl T., '04
Schurman, George W., '14
Schwerin, C. M., '01
Schwarz, Justin O., '09
Semple, Clarence C., '04
Semple, R. A., '12
Sen, J. T. E., '14
Sengstaken, J. H., '14
Sethna, N. R., '13
Sever, George F.
Seward, J. Perry, '90
Share, William W., '81
Sherman, A., '94
Skinner, Edmond N., '02
Slade, H. E., '09
Shaw, S. F., '03
Slichter, W. I., '96
Smith, Alexander
Smith, Frank M., '89
Smith, Lucian E., '01
Smyth, David W., '02
Soper, George A., '99
Spalthoff, William D., '14
Spiro, W. J., '01
Springer, A. P., '12

Stehli, H. J.
Stein, J. D., '14
Stern, Kenneth Gibson, '12
Stone, George C., '79
Stoughton, Arthur A., '88
Stoughton, Charles, '89
Struthers, Joseph, '85
Sturgis, Edward B., '95
Swortfigior, H. Braydon, '04
Talcott, M. G., '06
Tenny, Dwight, '14
Terrill, Arthur C., '14
Thomas, J. A., Jr., '14
Thomes, C. W.
Thompson, Milton S., '75
Thompson, M. M., '09
Thomson, S. C., '93
Thurston, Edward D., Jr., '07
Tiemann, Hugh P., '00
Timmons, W. J., '12
Titus, Warren H., '85
Tonnele, Theodore, '80
Trask, George F. D., '87
Trimble, Rufus J., '12
Trillech, B. L., '12
Tupper, W. D., '11
Tuska G. R., '91
Tyson, Levering, '11
Uhlig, William C., '96
Ungarleider, M. E., '14
Updile, D. M., '03
Valentine, H., '14
Van Arsdale, William H., '68
Van Winkle, Edward, '00
Vaughan, James A., '15
Vehslage, H. E., '07
Velebi, A., Jr., '15
Vom Baur, C. H.
Vondy, Rudolph H., '82
Von Muffling, E. Adrian, '10
Vredenburgh, Jr., Watson, '98
Vulte, H. T., '81
Wade, H. T., '93
Wainwright, Richard L., '89
Walker, Arthur L., '83
Walker, William B., '65
Wang, C. H., '14
Wang, Y., '16
Wang, Y. T., '12
Ward, Francis E., '81
Ward, Frank E.
Ward, Norman B., '13
Warner, C. M., '12
Warren, C. P., '90
Warth, Albin H., '07
Webster, L. S., '10
Weinrich, M. F., '04
Wendell, G. F.
Welch, Alexander M., '90
West, William D., '14
Westervelt, William Y., '94
Wheeler, Robert A., '13
Wheeler, Schuyler S., '83
Whitlock, Herbert P., '89
Wiechman, F. G., '81
Williams, Elliott
Williams, F. H., '74
Williams, Granville M., '11
Williams, John T., Jr., '99
Williams, Remsen T., '05
Williamson, A., '02
Wilson, W. A., '82
Wilson, William W., '08
Wise, Sidney L., '11
Wolff, W. A., '05
Wong, William A., '14
Wood, Roy U., '14
Woolson, Ira H., '85
Yerzley, W. A., '98
Young, Edward L., '82
Zimmer, Siegfried H., '14
Zoller, Harold P., '12

THE RECEPTION.

For the following account of the reception, on Thursday evening, May 28, we are indebted to the society editor of our esteemed contemporary, *The Alumni News:*

The first sound of revelry was by night and miners, young and old, had gathered in the Gymnasium their beauty and their chivalry. No threatening roar of cannon interrupted the pleasure of the first social event on the celebration programme, and all was merry as a marriage bell. Grizzled warriors of the underground realms, every vestige of copper ore and gold nuggets hidden under conventional garb and sunny smile, renewed old friendships, bantered alumni of recent years, and

took their keenest enjoyment in demonstrating that, tariff or no tariff, competition in restraint of trade in hesitation and tango was still extant. Occasionally a venturesome proud papa would introduce one of the "younger Mines men" to his daughter, and the wise young alumnus, having seen said proud papa's friends flocking in considerable numbers about "Sam's daughter" promptly absconded with his prize to be seen no more except in some secluded nook where *she* taught *him* the *very latest* steps.

And what hosts the entertainers proved to be! College men, dignified lawyers, solemn doctors, faculty members with the onus of the lecture hall thrown into the discard for the time being — every department of the University was represented in the steady stream which flowed back and forth between entrance and reception line. The night was perfect for an affair of this kind — cool, but not too cool for those who would a-strolling go in the shadowy grove, warm but not too warm for full enjoyment of the music.

There was no absolute centre of interest. The hall resounded with the merriment as the crowd swayed from end to end of the gaily bedecked gymnasium — flags and banners were in evidence at every available point. Caterer Smith and his minions satisfied the wants of the inner Miners with an attractive refreshment menu as soon as the dance began.

THE CONVOCATION.

PROGRAMME IN OUTLINE.

(Detailed reports follow.)

OVERTURE, "Jubel" .....von Weber
CORONATION MARCH, from "Folkungen".....Kretschner
PRAYER .....by the Chaplain of the University
INTRODUCTORY ADDRESS .....by the President of the University
ORATION IN COMMEMORATION OF THE FIFTIETH ANNIVERSARY OF THE FOUNDING OF THE SCHOOL OF MINES.....by HENRY S. MUNROE *
GREETINGS:
From the Royal School of Mines, London .....by T. A. RICKARD
From the Konigliche Bergakademie, Freiberg, by DR. FRIEDRICH KOLBECK
SINGING, "COLUMBIA, COLUMBIA, TO GLORY ARISE."
ADDRESS, "MINING AS A PROFESSION" .....by HENNEN JENNINGS
MUSIC, Selection from "Die Walkuere" Wagner
ADDRESS, "THE MINING ENGINEER AS A PIONEER"...by T. A. RICKARD
MUSIC, March from "Feramors" .....Rubenstein
CONFERRING OF HONORARY DEGREES. Candidates presented by JOHN H. VAN AMRINGE †
SINGING, "STAND COLUMBIA"
BENEDICTION.....by the Chaplain of the University

* Owing to the protracted illness of Professor Munroe, and his absence in Europe, this oration was included in the address by the President.

† Owing to the inability of Dean Van Amringe to be present, the candidates were presented by WILLIAM BARCLAY PARSONS, '82.

Prayer by the University Chaplain.

Almighty God our Heavenly Father, by whose hand all things are made and by whose spirit sustained, accept our gratitude which we now offer thee. We thank thee for thy world, for its vastness and riches, and for the inestimable treasures stored up in its everlasting hills and in the bowels of the earth. We rejoice in the men of intellect and genius, the men of brain and brawn, whom thou hast raised, who have tapped and opened the veins of the earth and brought forth to the light of day its hidden treasures of wealth for the benefit of mankind. Grant that we may remember worthily the high foundation that has been laid here by our School of Mines and by the University, ever strong and famous throughout the world because of the high ideals to which it has steadfastly adhered from its foundation. May we never be tempted to depart from those high ideals by the seduction of personal gain or other influences, but be always loyal to our Alma Mater. Gladden our lives by the consciousness of our common bond of loyalty and fidelity to our Alma Mater and to all mankind; and in all our relations with our fellow men may we always look upon them as our brethren and make service our goal. Grant us the love of humanity and an insight into true wisdom, so that in the end we may lay down our work in peace and honor. This we ask in His name. Amen.

Address by President Butler.

It is my pleasant duty to open this Convocation with a greeting of welcome to the Alumni who have assembled here today from far and near to participate in commemorating a very important educational event, an event of importance not alone in the history of Columbia University but of far reaching consequence in the history and development of higher education in the United States. You have come back here today to scenes and places that are in themselves new and intensely modern, to pay tribute to an idea and to the memory of the men whose shadow that idea represents.

It is not easy for us to put ourselves back into the position of our predecessors of half a century ago and to view the world as

they then saw it. When the School of Mines of Columbia was founded, this country was engaged in the throes of a civil war, of which the outcome even then seemed extremely doubtful. There were in evidence on the continent of Europe, and especially in Great Britain, radical differences of opinion that bid fair to disrupt the political and social history of the world. Men's conceptions of higher education and its field were changing. New ideas, new thoughts, new interpretations of old phenomena were being pressed upon the attention of mankind everywhere. What more fitting than at such a time, when there was not only the invitation but the absolute pressure of material necessity, the minds of broad-minded, far-seeing men should be turned to the advantage of undertaking some activity that would harness science into the service of mankind? How could that better be done than by the training of men in the arts and sciences of mining and of metallurgy, to enable them to tap successfully and skillfully the mineral resources of old Mother Earth, and to find new ways and means of putting such resources at the service of mankind

The hour was ready and the men were at hand. But curiously enough, and as has happened so often in the history of all institutions, the idea that was then to project itself and be brought by Professor Egleston firmly to the attention of the Trustees of the old Columbia College was an idea with which they were already familiar. It is one of our boasts here at Columbia that our forefathers and founders were far-sighted, and that their vision was so keen and their viewpoint so elevated, that nothing that we have since been able to think of and do ever escaped them. Let me read to you a passage from President Samuel Johnson's famous first advertisement of King's College, issued to the people of the Province of New York in 1755:

> A serious, virtuous and industrious course of life being first provided for, it is further the design of this college to instruct and perfect the youth in the learned languages and in the arts of reasoning exactly, of writing correctly and speaking eloquently, and in the arts of numbering and measuring, of surveying and navigation, of geography, history, of husbandry, commerce and government; in the knowledge of Nature in the heavens above us and in the air, water and earth around us, and the forest; and in all stones, mines and minerals, plants and animals, and of everything for the comfort and convenience and elegance of life, and in the chief manufactures relating to any of these things.

It is difficult to withhold admiration from the statesmanlike view of our first President, who stated in the elegant language of the eighteenth century precisely the ideas that the School of Mines, more than one hundred years later, was established to carry into effect.

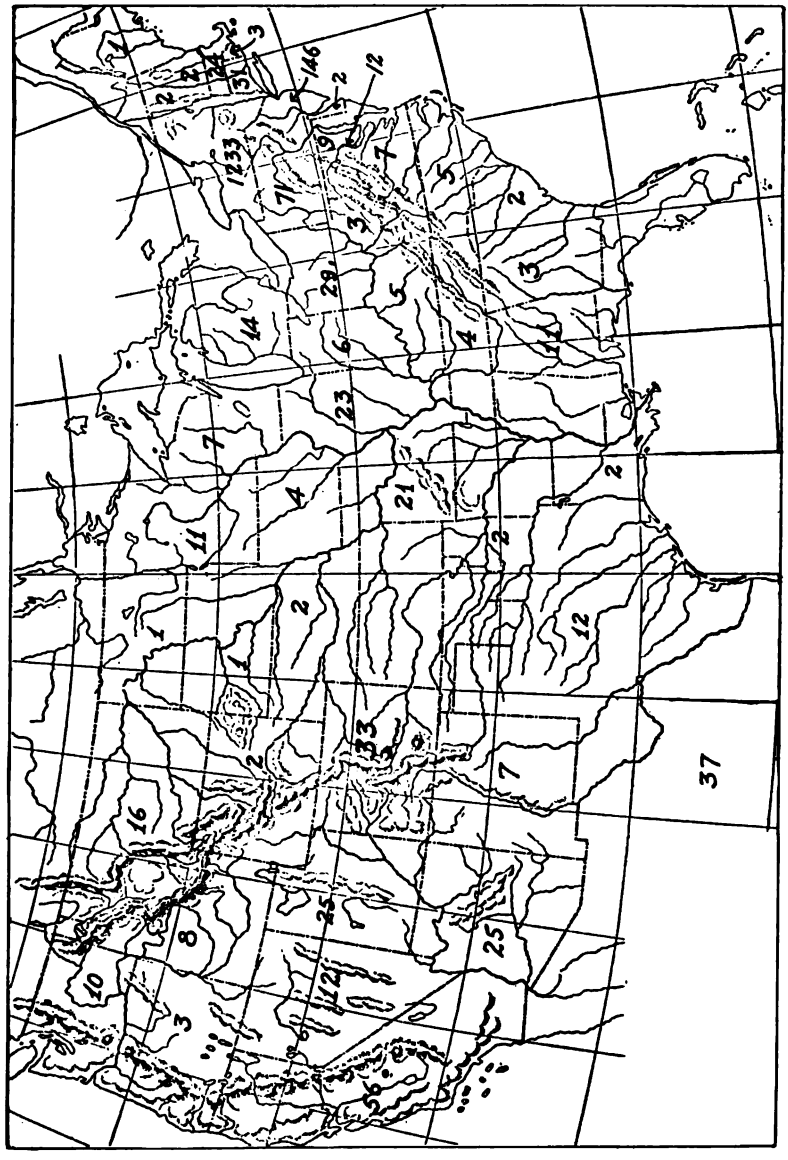
Once again, toward the close of the fifth decade of the nineteenth century, a movement for the development of a real university at Columbia had begun, and the trustees' committee included this in their plan:

> A school is established, called the School of Science, in which shall be pursued the following studies: Mechanics, physics, astronomy, chemistry, mineralogy, geology, palæontology, engineering, mining and metallurgy, arts of design, history of science, natural history, and physical geography.

So, again, the highest legislative body of the University in 1857 contemplated, but a little too soon to carry into effect, precisely such an undertaking as the School of Mines was soon to make practical. Thus it is for these reasons, gentlemen, that in this pamphlet entitled " Plan for a School of Mines and Metallurgy in New York City by T. Egleston; New York, March, 1863," which has been reprinted for distribution through the generosity of Professor Chandler for his colleagues at Columbia, and for the use of the alumni present at this fiftieth anniversary celebration of the School of Mines — for these reasons the idea contained in this pamphlet was accepted and carried out. The idea itself was thoroughly in accord with the propositions and aims of old King's College and Columbia College, its successor. What had heretofore been lacking were men and means, men who could formulate plans and get the means with which to carry the idea through when once started.

It is one of the wonders of the world that this undertaking was able to be begun with men alone. I know of no successful educational enterprise that ever began with less material support than this did. It rested almost wholly upon the generous enthusiasm, the vision and the personal faith of a group of men, who compelled the resources slowly but steadily to come to their support; and today, as a result, you have the great School of Mines and its associated schools. But, bear in mind that if Egleston, Vinton, Chandler, and the rest, had waited for a great endowment they would

have been waiting yet. They made the School of Mines what it is mainly by their unselfish, devoted efforts; and, as the silkworm



DISTRIBUTION OF SCHOOL OF MINES GRADUATES IN UNITED STATES — 1912.

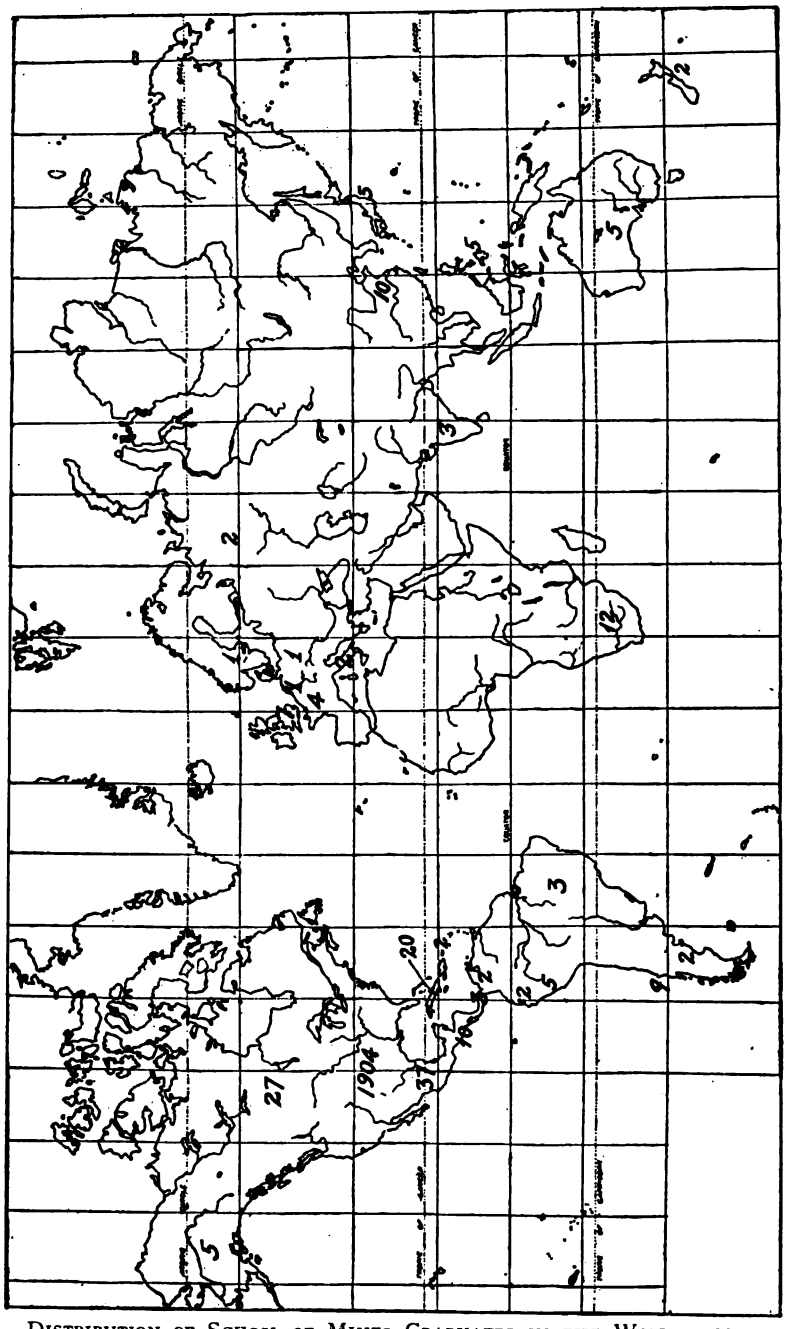
finds in its own structure the material with which to make the most valuable thread known to commerce, so they found in their prin-

ciples and generous impulse this great contribution to this University and to American education. And when today we commemorate the founding of the School of Mines of Columbia University, let us commemorate with grateful and appreciative hearts its founders, the men behind the idea, and also the men among the trustees and the older faculty who were associated with them and held up their hands.

The School of Mines has, therefore, once more illustrated the old adage that an institution is the lengthened shadow of a man. This institution is the lengthened shadow of a noble group of men; and it is a glory and a satisfaction that one of that little group who for nearly fifty years labored unselfishly and unceasingly at his executive post of duty, whose personality has long since wound itself around the hearts of each and every one of us, is present with us in full health and vigor on this occasion.

The story of the School of Mines was to have been told to us today by my colleague, now the senior professor in the service of the University, the senior professor of mining, Henry Smith Munroe. It is a matter of regret to all of us, and particularly to me, that the illness which caused him to seek rest and recuperation abroad, in the confident hope of being able to come back to participate in this celebration, has not sufficiently abated to permit him to return here so as to be with us. He is, however, gaining in health and strength in the highlands of Switzerland, and I know that I am speaking for him when I offer you his cordial and personal greeting and good wishes, and I also know that I shall be speaking for you when I return to him by the electric spark your message of regret at his absence.

The history of the School of Mines is known to all of you. It has long since ceased to be an academic Cinderella, owing to the generous benefaction of Mr. Adolph Lewisohn, whom we are glad to greet here today as a colleague and friend. The School of Mines has an adequate and beautiful home of its own. It stands as the primary representative of the University's undertakings in the realm of pure and applied science. I have sometimes seen the suggestion that somehow or other the name of the School of Mines has been changed. It has not been changed; it never was changed; and it never will be changed. Nobody ever dreamed of



DISTRIBUTION OF SCHOOL OF MINES GRADUATES IN THE WORLD — 1912.

changing the name of the School of Mines. The School of Mines has had children, grandchildren, cousins, uncles, and aunts, but it has clung to its name, the School of Mines. The very name of the School of Mines has for us here at Columbia, in the mines of the far West, in Mexico, in South America, in South Africa, in Australia, in fact all over the wide world, a psychological suggestiveness. With all due respect to other schools of mines in the world, the term "School of Mines" calls up but one image to us Columbians. The term "School of Mines" is a proper noun. It is *our* School of Mines; that School of Mines which has undertaken the leadership, the direction, the inspiration and the development of scientific enterprise at Columbia this last half-century.

Fifty years ago it was confined to a dark basement, with $500 in money and a small collection of minerals. This undertaking, and the others connected with it, have grown into a charge upon the University's general income of $400,000 a year, by far the heaviest single charge that the University bears at the present time. The great Schools of Law and Medicine combined do not begin to equal, with all the expensiveness of modern medicine, the cost of carrying on these great activities in science; but, as a return, the University has the great School of Mines, of which it is justly proud — whose graduates have girdled the earth; and in the hands of the men into whose eyes I look today, and of your absent colleagues, it has ever borne, and I trust ever will bear, an unstained, enviable reputation. The name of the School of Mines, as I said before, will not only never be changed but will be gladly and cheerfully sustained and maintained just so long as the men are at hand to make the service and the sacrifice not only worth while but an investment in the highest public interest.

Look at our great school of today! In a family gathering like this one may be pardoned if he boasts. In mining, I point with pride to Munroe, to Peele, and their junior colleagues; in electrical engineering to Pupin, to Schlichter, to Morecroft, and their junior colleagues; in civil engineering to Burr, to Lovell, to Blanchard, and their junior colleagues; in mechanical engineering to Lucke, to Rautenstrauch, and their colleagues; in the great department of chemistry, founded and built up by Dr. Chandler, to Alexander Smith, to Bogart, Whittaker, Morgan, and a host of their col-

leagues; in the departments of physics and mathematics to Keyser, Wills, Pegram, Fiske, Maclay, Wendell and their colleagues; to Kemp in geology, to Moses and Luquer in mineralogy. In the hands of the men whose names I have mentioned, and in the hands of their colleagues and successors, the future of the School of Mines is secure.

GREETINGS FROM THE ROYAL SCHOOL OF MINES.

CONVEYED BY T. A. RICKARD.

I have the honor to bring the congratulations and greetings of the Royal School of Mines, of London, now a part of the Imperial College of Science and Technology. It is here written:

To the School of Mines of Columbia University:

The Governors of the Imperial College of Science and Technology, and of the Royal School of Mines, take keen pleasure in accepting the invitation to send a delegate to the fiftieth anniversary of the founding of the School of Mines of Columbia University, and are glad of the opportunity to tender their hearty felicitations on this auspicious event. They regard with admiration the services done by the Columbia School of Mines in training the men who have taken a prominent part in the development of the mineral resources of the American continent, and they view with fraternal good-will the useful influences exerted by the graduates of the Columbia School of Mines in the advancement of the mining and metallurgical professions in America.

Signed and sealed in pursuance of resolutions of the Governors the 27th of February, 1914.

ALFRED KEOGH, Rector.

(Three cheers for the Royal School of Mines! were called for, and given).

PRESIDENT BUTLER.— I have the honor to acknowledge this message of greeting from the Royal School of Mines, of London, and beg to express to it and to its bearer our sincere and appreciative thanks.

GREETINGS FROM THE KÖNIGLICHE BERGAKADEMIE, FREIBERG.

CONVEYED BY DR. FRIEDRICH KOLBECK.

On behalf of the Royal School of Mines at Freiberg, in Saxony, I desire, first of all, to thank you most sincerely for the cordial invitation to assist in the celebration of the fiftieth anniversary of the Columbia School of Mines of New York City. The Faculty of the Royal School of Mines greatly appreciate the privilege of sending a representative to New York for this celebration, and they have delegated me to bring to the Columbia School of Mines their message of hearty and sincere

congratulation. As I now perform this pleasant duty, I am conscious of the high distinction that is thereby also conferred upon me.

The founding of the Columbia School of Mines, fifty years ago, was for this country, so richly blessed with valuable mineral deposits of every sort, a matter of necessity.

It is a most interesting and fascinating matter to trace the amazing development of mining and metallurgy in the United States within the past fifty years. We in Freiberg well know how much the Columbia School of Mines has done for the mining industries of this country and for the proper exploitation of America's mineral wealth. Scholars and engineers of world-wide renown have given and still continue to give their services to the Columbia School of Mines. It has trained large numbers of efficient and well known men, who have spread the fame of their *Alma Mater,* not only throughout the United States, but wherever the miner digs for the treasures of the earth and wherever the smelter has set up his smoking chimneys.

The School of Mines at Freiberg, the oldest in the world, and, at the same time, the oldest technical school of university rank, brings to her younger sister heartfelt greetings, and expresses the hope that the Columbia School of Mines may further continue to develop and flourish. In this hope it extends to the Columbia School of Mines the time honored greeting of the German miner: *Glückauf.*

PRESIDENT BUTLER.— It is a great pleasure for us to receive this greeting from your colleagues in Freiberg from your hands, Dr. Kolbeck. I beg that you will express to your colleagues in the School of Mines at Freiberg our sincere appreciation.

(Three cheers for Dr. Kolbeck and Freiberg! were called for and given).

COLUMBIA, COLUMBIA, TO GLORY ARISE.

Taken from the original "Ode to Columbia," written in 1777, by Rev. Dr. Timothy Dwight, and dedicated to the Fiftieth Anniversary Celebration of the School of Mines. The origin of the name "Columbia" has been traced to the patriotic poem which was written by Rev. Dr. Timothy Dwight in 1777, and widely sung by the soldiers of the Revolution. All the lines of the present song except three words are taken from the original poem, re-arranged, and set to new music.

Words adapted by
Arthur S. Dwight, '85S

Music by
Percy Lee Atherton

Columbia, Columbia, to glory arise!
The Queen of the World, the Child of the Skies!
Thy genius commands thee! Thy heralds proclaim —
Be freedom and science and virtue thy fame!
A world is thy realm, for a world be thy laws
Enlarged as thine empire and just as thy cause.

On freedom's broad basis that empire shall rise,
Extend with the main, dissolve with the skies;
Thy heroes the rights of mankind shall defend,
And triumph pursue them and glory attend,
While the ensigns of union, in triumph unfurled,
Hush the tumult of war and give peace to the world.

Fair science her gates to thy sons shall unbar,
And the east see thy morn hide the beams of her star;
New bards and new sages unrivalled shall soar
To fame unextinguished when time is no more.
Columbia, Columbia, to glory arise!
The Queen of the World and the Child of the Skies!

[We regret that it is not feasible to reproduce the music of this song, a copy of which was provided for every person in the audience. The composer has succeeded well in combining a harmonious melody with a vigorous swing.— Ed.]

COLUMBIA UNIVERSITY, MORNINGSIDE HEIGHTS. SCHOOL OF MINES AT LEFT.

MINING AS A PROFESSION.

BY HENNEN JENNINGS.

To consider man without the earliest primitive contributions of the miner and metallurgist takes us back to savagery. Man's greatest endowment is his wonderful and crafty brain cells with their latent powers of development, which have shown him the necessity of supplementing his own strength by outside aids, and then gradually and persistently obtaining the materials for his needs and fashioning them into tools of power, and finally incorporating and making them a veritable part of his being.

His first great advances were the commanding of fire, the use of stone implements, then wooden bow and arrow. By these he worked himself into the stone age, but was still brutal, weak, and with little historical recording power. It was not until he delved below the surface of the earth for materials that he was able to fashion the sword, spear, fire-arms, protective armor, plow, hoe, pruning-hook, pitchfork, scythe, tires, axe, saw, plane. It was only with metal tools that great agricultural development began and it reached its present magnitude only when further supported by the metals in such form as railroads, steam vessels, and harvesting machinery.

Basic Industries.— Mining and agriculture are the two principal basic productive pursuits of man, and they are fostered each by the other, both being dependent on mother earth. The one skims her surface, the other goes deeper. Agriculture furnishes man with food for existence, but mining gives him the materials for power, art, and civilization. Without metals the scientists' tools for experimentation and determination would not be possible, nor the great diffusion of knowledge and thought by means of the printing press, photographic appliances, telegraph, cable, and the telephone.

Nothing can more forcibly illustrate the might of man as given him by the metals than the modern battleship. What could all the war vessels of history, up to 20 years ago, do against one modern battleship adequately supplied with ammunition, if they were drawn up in open battle array? Could not this one ship, by its superior speed, gun-power, and armor, annihilate at will the whole fleets of

history, even if commanded by Vikings, Nelsons, and Farraguts? Is not the control of sea power the cardinal factor in war, and thus has not modern man become a war god indeed by means of his engineering genius?

In contrast to the bewildering might of the battleship's guns, with their projectiles of 1400 lb. weight, and 2600 ft. per second velocity, the metals have given man fingers delicate, untiring, and accurate, to control threads so fine that fleecy muslins and laces grow in abundance under their touch.

Statistics.— Let us now deal with mining on a solid and broad statistical basis, attempting afterward to clothe the dry bones of statistics with further meaning. In this brief sketch it is not possible to incorporate the statistics and results achieved in mining in all countries. What is selected, it is hoped will be considered typical for all countries, and instructive to all interested in mining in a big way.

Great Britain produced more coal than all other countries of the world together until 1871, and more iron until 1885. The British Empire now produces 60% of the world's gold. It was only in 1899 that the United States surpassed Great Britain in coal output, and in 1897 took the decided lead in iron.

Germany's production of iron exceeded that of Great Britain in 1905, and it now mines about the same amount of coal. To Germany must be accorded priority in mining literature and technical training, as evidenced by the publication of Agricola's *De Re Metallica* in 1556. The Freiberg and Berlin technical schools were founded in the 18th century. The first English-speaking school of mines was that of the Royal School of Mines, London, founded in 1853. Although having but a small output of graduates per year, it has been distinguished for the scientific eminence of its professors and the loyalty and ability of its graduates.

World's Mineral Production.— The world's mineral production for 1912 shows that the United States produced 20% of the gold, 39% of the coal, 63% of the petroleum, 41% of the iron, 55% of the copper, and over 30% of the lead and zinc, which gives it an undisputed lead over any other one country. The statistics of the United States are thus most representative, and, as the most available to the speaker, they will be extensively used. Difficulty of

obtaining reliable, comprehensive mining statistics increases immensely as one goes back into the past, but, on the other hand, there is less and less to record. It will be typical and instructive to examine the last official statement of mineral products of the

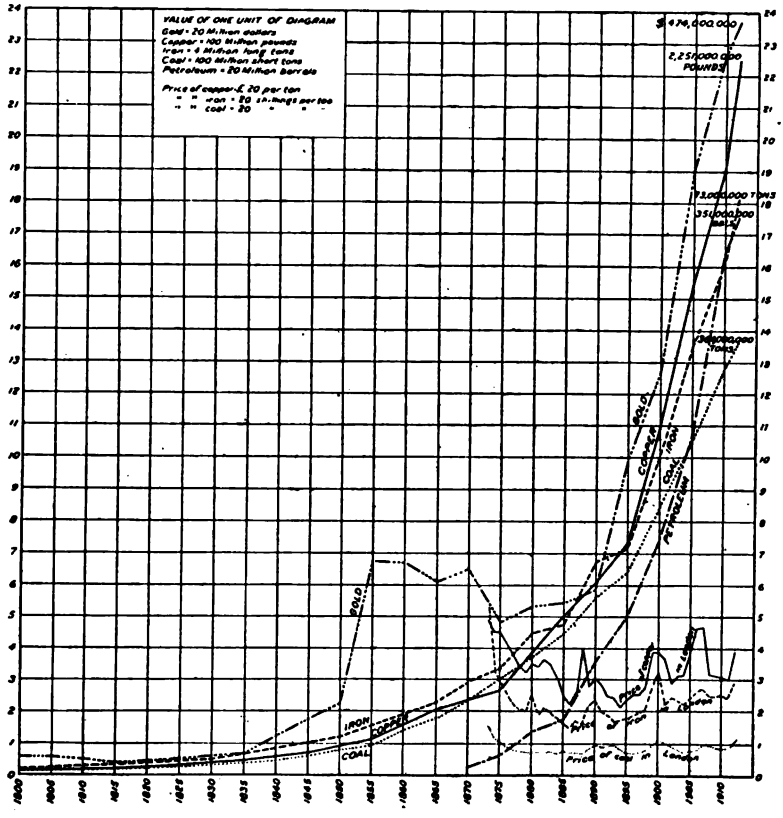


DIAGRAM NO. 1; THE WORLD.

United States, as given by the Geological Survey for calendar years 1903-1912.

In 32 years, the production of the metals has increased from $186,000,000 to $867,000,000, or 475%; the non-metals from $175,000,000 to $1,376,000,000, or 755 percent. In the 10-year statement, 71 mineral products are tabulated, all showing material yearly increases in production. Note especially the great and striking increase in the production of aluminum. The increase in cement records the great growth of modern concrete construction.

The output of sulphur in various forms indicates the sulphuric acid consumption, and thus gauges the growth of the chemical and industrial arts. The phosphate rock production points to the ever increasing help which mining is extending to agriculture.

Of the total valuation of $2,224,000,000 for all the products from the United States in 1912, coal, petroleum, iron, copper, and gold were estimated at $1,579,000,000, or 70%. These metals are so representative and vital that a just and comprehensive idea of the growth of mining, metallurgy, and engineering can be obtained by following their production. This, in a broad way, can be best done by diagrams, large units of products being plotted to small scale.

Diagram No. 1 * shows the world's yearly production of coal, petroleum, iron, copper, and gold from 1800 to 1912, and also gives the average London price for the units of these products back to 1873.

Diagram No. 2 gives a similar data for the same mineral products in the United States. The prices per unit of the products are estimated at place of production, and cover a longer period. It further shows the growth of the whole population of the country since 1800; the number of men engaged in mining since 1850; the increase in railway mileage since 1840; also the growth of deposits in all reporting banks in the United States since 1867.

From the world's diagram it can be calculated that the last 15 years' production of coal has been equivalent to the 97 previous years. That the last 8 years' production of petroleum has been greater than all previous years in history. That the last 12 years' production of iron was equivalent to the 100 previous years. That the last 11 years' production of copper was equivalent to the 101 previous years. That the last 17 years' production of gold was equivalent to the 95 previous years.

Magnitude of Mining.— The wonderful modernness of big mining can be further realized by attempting to obtain statistics of pro-

* Mr. E. W. Parker, of the United States Geological Survey, extended effective and kind aid in the obtainment of the data for the mineral production. The data for the bank deposit curve was taken from the National Monetary Commission Report. The growth of population, miners, and railways are as given by United States census returns. The discovery of gold in California and Australia caused the great jump of the gold curve 1850-1865.

duction previous to 1800, such attempts leading one to the belief that all the coal, iron, and copper mined in all ages, for the whole world, prior to this date would not amount to the probable world's

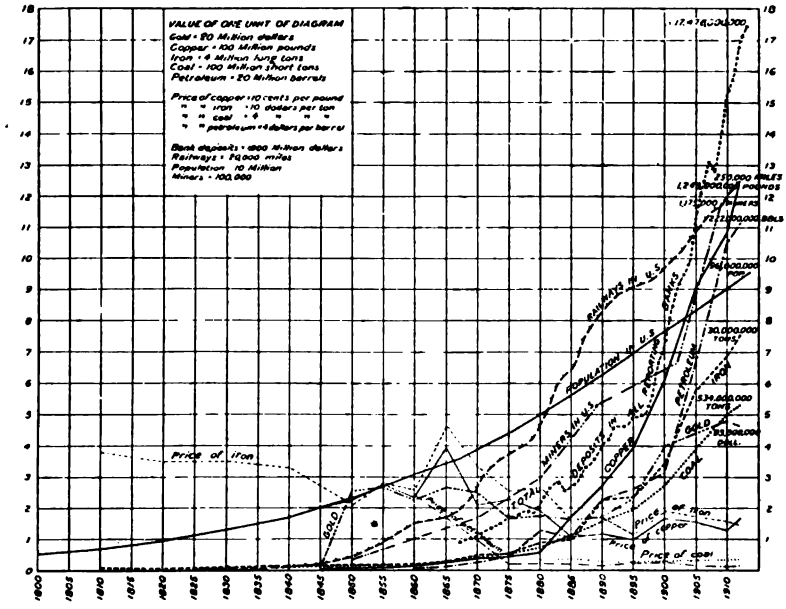


DIAGRAM NO. 2; UNITED STATES.

production for the years 1913 and 1914. Petroleum practically came into use only in 1860. It is estimated that the total production of gold from 1493 to 1800 was $2,371,000,000, whereas from 1800 to 1912 it amounted to $12,411,000,000.

It will be found that the selling prices of mineral products at the London market and at place of production in the United States were higher in the early years than the later ones. Thus the present great increase in cost of living is not to be found in the unit advances of the products of the mineral kingdom. It is interesting to know that the cost per ton for coal at place of production is less in the United States than in Great Britain.

Fuels — Coal and Petroleum.— Fuels are most necessary for the metallurgy of the metals and are storehouses of energy. In 1912 the United States coal production was 534,000,000 tons, and petroleum 222,000,000 barrels. They both have great industrial value

besides that of fuel, but our time will not permit of this consideration, nor do we include natural gas in our estimates. To obtain some idea of the meaning of the force locked up in these enormous amounts of fuel, it is only necessary to calculate the work that would be given out if they were all (as is largely the case) used for the production of steam-power, with, at best, not more than 15% of the latent power utilized.

Petroleum in the form of gasoline can be more efficiently used for power in the internal combustion engine, but reducing the 222,000,000 barrels to the coal equivalent of 51,000,000 tons, we would have the steam force of 585,000,000 tons of coal. Dividing this among 100,000,000 inhabitants would give 5.85 tons per capita. The equivalent of 5.85 tons can be taken at 5850 horse-power hours, or as much energy as would be given out at pumping by a man in 9850 days, or 27 years. This coal could thus give out force by the steam-engine equal to a population of 2,700,000,000 strong men.

The life of coal and petroleum deposits has been variously estimated. Should the increment of increase in yearly production continue, the known fields of petroleum would probably be exhausted within a comparatively few years, and coal in one or two centuries, but should the present population and per capita consumption not greatly increase, the coalfields might last one or two thousand years, and the petroleum possibly a hundred.

Should fuel outputs continue progressively to increase, greater and greater numbers of the population must be employed in their mining; also a greater and greater percentage of people would be required to generate, control, distribute, and pay for the power manufactured. There must be, therefore, a point where the population becomes saturated with power and can use or pay for no more per capita. The fewer the workers, the less the number of hours they work, the less their efficiency, the sooner will this saturation be reached. This may still be a long way off, and may be greatly influenced by future invention, but approach is steadily being made toward it. It will be the determining factor for final outputs.

Useful Metals — Iron and Copper.— This group includes tin, lead, zinc, quicksilver, aluminum, platinum, etc., but it is not feasible to deal with them all, and iron and copper are the mainstays and the most useful of the metals.

Metals in useful form can not be readily obtained from their ores without fuel. On the other hand, the fuels can not be chained to great service without the use of the metals — for example, in the form of steam-power. The metals can be made use of independently of the fuels in manufacturing power from falling water, rising tides, vigorous breezes, and possibly burning sun. They are essential, as has been explained, for all manner of necessary tools and implements. Of late copper, through dynamos and motors, has revolutionized the production and flexible use of power.

In considering the importance of the yearly production of those metals, it must be taken into consideration that they are not destroyed when once used, as is the case in the fuel group. They are put into machinery and tools that may last for many years, and are again given new life by fire and fashioned into other tools and machinery whenever the economic conditions justify such regeneration.

On the other hand, the metals, including the precious, are far less abundantly distributed than the fuels, and their more speedy exhaustion is a matter far more imminent and serious. The utmost parts of the world have been searched for gold, silver, copper, platinum, tin, and nickel. Naturally the deposits of these metals that are in most striking evidence and abundance have already been found. In the future there will be less cream to skim, and more thorough and costly exploration and prospecting will be required. Exhaustion of the metals, even under the present basis of output, is not so very far afield, and their discovery, conservation, and right working becomes more and more a matter of importance and difficulty, and should be given serious and broad public consideration.

Precious Metals — Gold.— Under this group silver is usually included, but gold alone will be discussed. Gold has a limited use in the arts, also as an ornament, but its chief value is as a concentrated and convenient standard of barter. Whether this started on a basis of caprice or custom, it is now firmly established on a labor basis of value. Gold coins can be considered storage cells of human energy that give out a strong and genial current of trade confidence, circulating and binding trade, and bringing together industries of different peoples, in different lands, with different customs. The vitality and value of these cells is the labor elements poured into them — in other words, the human difficulty of their obtainment.

The history of gold mining is almost uncanny in that it has for ages shown success and failure so hand in hand that it has taken a full labor equivalent to obtain the gold unit.

In the greatest of all gold mines in history, those of the Transvaal, there are employed nearly 200,000 black and 26,000 white men to get out a yearly return of $180,000,000, and this does not include the labor expended on the supplies and machinery shipped to the mines. It has been found that nearly three-fourths of the output, even of the successfully producing mines, has been required to meet their current working expenses.

It may seem a waste of human energy to pay so much in labor for the circulation of financial confidence, but confidence is necessary and vital, and easily disturbed. When nations can have sufficient confidence to do away with their costly war equipments of metal, they will probably also be able to do away with the gold metal standard. There does not, however, seem to be any immediate hope of their doing either, and the limitation of gold mining may be found rather in its increasing scarcity and difficulty of obtainment, as the present goldfields seem to have about attained their zenith.

Engineering Societies and Schools.— Diagram No. 3 * shows the birth and growth in membership of the six main technical engineering societies of Great Britain, which, in 1912, totalled about 30,000. Diagram No. 4 shows the growth in membership of five of the technical societies of the United States, which, in 1912, totalled about 24,000. The diagrams show the sudden and sympathetic growth of membership of the societies in parallel with the production of the minerals, and is especially noticeable for the mechanical and electrical engineers when compared with the production of iron and copper.

Upon diagram No. 4 the enrollment curve of students in all branches of engineering at Columbia is given and again shows marked accord with the growth of mineral production. The Columbia School of Mines, the oldest and most renowned in the United States, is also a part of one of the largest and most important schools of applied science; although it is only one of the many in

* The curves of growth of Great Britain societies have been prepared by Edgar P. Rathbone. Those for the United States are as given by the American Society of Mechanical Engineers, January 1914. The Columbia School of Mines curve has been prepared by Dean Goetze.

the United States. The Bureau of Education (Department of the Interior) in 1911 gave in round figures the total enrollment for the technical students in all schools, colleges, and universities of the United States, as follows: Civil engineers, 9,000; electrical engineers, 6,100; mechanical engineers, 7,000; mining engineers, 2,300;

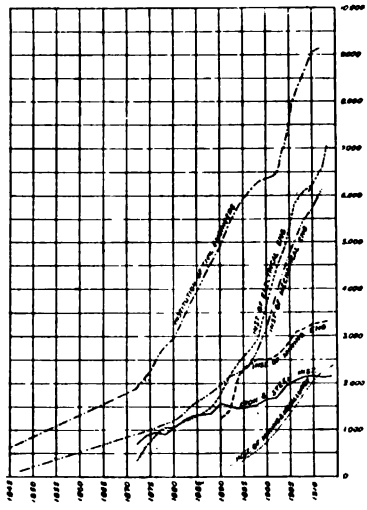


DIAGRAM No. 3; GREAT BRITAIN.

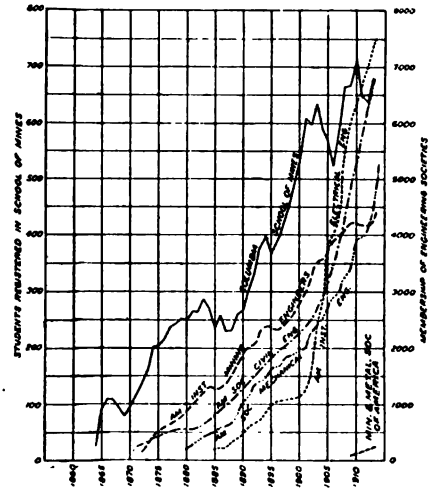


DIAGRAM No. 4; UNITED STATES.

a total of 24,000. Note how this is in tune with the membership of the engineering societies of the United States.

The number of technically trained men required by the mining industry has been most ably and interestingly dealt with by Professor Christy of the University of California in 1893, and President McNair of Michigan University in 1905. They both show that although the number required was not then large in the aggregate, it was in ratio to the production and number of men engaged in mining.

Upon diagram No. 2, it will be noted that the growth of railway mileage is more nearly parallel with the growth of mineral products than with that of the population of the United States. The relation of railroad transportation to mining is most marked and important, and was the subject of an able address given by Dr. Douglas to the graduating class of your School of Applied Science in 1906. He then showed that the production of iron and the building of rail-

roads had kept step in the United States since 1840. He also showed by tabular statements that from 45 to 58 percent. of the traffic movement of the United States was in connection with products of mines. Later statistics only confirm this statement, and would indicate an even higher proportion.

Discussion.— In a broad way, let us now read some of the lessons that the foregoing diagrams and statistics seem to give us. It would appear that mining and metallurgy, after dwelling in a lowland of drowsy accomplishment for centuries, then pioneered and stimulated by great gold discoveries, sprung into gigantic activity, and by leaps and bounds, all within the life of this School of Mines. This has been brought about by the growth of knowledge through science, invention, and engineering, which first made clear the possibility, and finally the way, of the manufacture of power on a scale never dreamt of before, and thus giving man almost an Aladdin's power of summoning and enchaining a gigantic retinue of obedient impersonal servitors.

All branches of engineering have eagerly and ably contributed to this accomplishment, but they could never even have started without the miner. Do not the force currents that have been generated from mining products, and controlled and set in circulation by engineering skill, supplement or supplant manual work and thus constitute the basic cause of the growth and might of modern wealth? Look at the indicator gauge of bank deposits, and bank circulation! In contemplating this flow of force, are we not impressed with the analogy between the circulation of blood in our bodies, and the wealth currents in trade? Does not a sudden halt and stoppage mean paralysis or death in either case, for circulation is vital to trade as to life? The arteries of commerce require veins for distribution and return as does the body. All parts of the body, even the brain, have limited absorbing power and must return the remainder to the moving blood currents, and thus the richest of men have but small individual wealth-absorbing power and must let the rest of the current go through them. They can be a great artery of flow, but not a terminal reservoir.

It is quite natural that bewilderment and unrest should follow the sudden might of this ever-growing flood of power summoned from the mineral kingdom — more time, more patience, and more indus-

try are required to understand and govern it aright. Force uncontrolled or misunderstood is dangerous in proportion to its magnitude, but as it is harnessed and controlled by a serene and equitable understanding, so must it benefit and redound to the service and advancement of man.

To obtain the great production of minerals for the manufacture of force, and then its various useful transformations, has required not only the creation of huge and complex manufacturing tools, but also new great implements of finance, and thus the growth of the limited liability corporation and the stock exchange has been in sympathy with the mineral production. Over-eagerness to drink of the force fountains produced over-promotion and over-competition, which demanded in turn remorseless skimming of cream without any reckoning of the future, as is shown by the wasteful methods of mining and extravagant use of fuels, and the intensive, remorseless use of labor, both of hand and brain.

To obtain the effective dollar, for legitimate enterprise, by means of the stock exchange, many are circulated in demoralizing gambling. The capriciousness of ore deposits is an acknowledged fact and problem in mining, and the wise balancing and weighing of probabilities and possibilities, so as to make good guesses, based on slender foundations, is the great and final accomplishment of the successful mining engineer.

Hazards of Mining.— Mining is not an unreasonably hazardous business if its capriciousness is recognized and if initial payments for unproved chances are not made too great, and expenditures for equipment are not undertaken upon insufficient foundations, and risks are averaged by spreading them. Advantage has been taken by company promoters and manipulators of the legitimate uncertainties of mining to excuse the wildest mining ventures and the exploitation of stock certificates, rather than ore deposits. This has handicapped legitimate mining by making it difficult to obtain promising initial prospects at sane prices for purposes of honest test. It also tends to belittle the good name of a basic industry upon which modern civilization rests.

The fallacy of the belief that mining can thrive only through the stock exchange is known to those who have been connected with big mining affairs, and have seen that successful enterprises have

been initiated and carried through dark days of slow development and depression, by people who have knowledge, courage, and money to back their convictions. The stock exchange shows its greatest activity when least needed, that is, in inflating success and exaggerating failure. The transactions of the mining and other engineering societies, as well as the honest and high-class publications of the leading technical press, are giving such educational light that it is hoped and believed that mining exploitation by the stock exchange is very much on the wane.

To be fair to the stock exchange, it has often caused successful mines to be developed, which otherwise would not be worked, but the profession with which I am dealing has not the stock exchange as its guiding star. It must nevertheless be acknowledged and understood that mining is not undertaken for making statistical showings, nor for philanthropic purposes. Its fundamental idea is to make money for those who undertake it, and the success of the mining administrator or engineer is largely gauged by the return of profits he can show.

After the protection of the lives of his workmen, rightly the engineer's first duty is loyalty to the owners of the enterprise that employs him. The owners, who put up only their own money, have a right to decide to what extent they make their business and engineering information public. But, when a limited liability corporation is formed, the case is entirely different, for this means the partnership becomes unlimited, and, as all partners have right to knowledge, the engineer's loyalty to his owners changes from the few to the many.

In writing reports for private owners, the engineer should protect himself and the public by placing before himself, and then on record, all facts obtainable in any way bearing on the problem, and then, and only then, write his conclusions, submitting the report to his principals upon condition that, if made public, it will be given in its entirety, or as edited by himself. The essence of engineering ethics is to obtain full truth, first for himself, then to give it in full to his employer. If this is done with industry and frankness, all the other ethical rules with which our engineering associations are struggling, will be but corollaries.

The secrets of mining should be more and more confined to those

given by nature. Mining titles and laws should be established with more certainty, so the most generous and honest are not handicapped or preyed upon, by the most shady and dishonest.

Educational.— The subject of the preparation of students for the mining industry has been a fruitful theme of papers in transactions, and addresses to colleges and universities, and it is not necessary for me to emphasize its importance.

The interlocking and parallelism of the educational needs of different branches of the engineering profession were clearly recognized and set forth by Professor Munroe ten years ago, who, at the same time, pointed out the necessity of a greater diversity of knowledge for the mining student than for any other branch of engineering. The decision of this University to demand from all applicants for engineering degrees a sound foundation of general culture before specializing, and equal to that preliminarily required in any other profession, is only in keeping with what I have endeavored to show to be the great responsibilities and powers, which have of late years been demanded of mining and other engineers.

Pioneers in Mining.— It is obvious that in the early days of big mining the accomplishment and numbers of technically trained men did not equal or fit the demand, and that many forceful, talented. energetic men must have risen from the ranks to leadership. They were the first in the saddle, and, naturally, did not always see the full necessities of training, without which they themselves had succeeded. But assuming equal individual ability, the wastefulness of acquiring knowledge by only personal experience, and not by making use of the stored experience of others, must tell against the merely practically trained man.

The great self-made mining men of the past must be recognized and reverenced, both in the technical societies and schools, for they have been the pioneers and makers of history. Though in time a degree from an engineering school may, and should be, regarded as a first necessity, the demand for it should not be made retroactive.

The student of the future should only regard his degree as the trainer's certificate of efficiency and soundness, for a race and struggle still ahead of him. Practice, as well as theory, is essential. The danger of only theory in formative years, even for the diligent student, is that the slowness of results and drudgery of practice becomes

distasteful, and commercial success not so palatable or satisfying as to those who work their way up from the ranks.

Your school of summer practical training, giving students a preliminary contact with actual work, is excellent so far as it goes, and its success has been shown by the extent to which it has been copied. It is to be hoped that even greater demand will be made by the schools for early practical experience, to be rewarded by a post-graduate degree. Students who have worked for wages and have obtained approbation of employers, and have been thrown in intimate contact at the formative time of life with the ordinary wages earner, on equal terms, have obtained an experience most desirable and most necessary for the engineer.

In these days of impersonal corporation ownership, the closest and most intelligent link between capital and labor is that of the engineer. To be of the greatest use he should know the life, ambitions, and viewpoints of each, and bring wisdom and sympathy to both sides in the bitter and dangerous struggle that is now going on between those so intimately bound together that the paralysis or death of one means the same for the other. Such experience can be advantageously obtained for the engineer only before he has assumed responsibility of leadership in dealing with labor.

It is the right labor viewpoint and basic principles of business economy that should be more and more taught to mining and other engineering students. Engineering training should not simply be limited to those certain to practice it — it should be used and looked upon as a gateway to leadership in all great business enterprises, for it is fundamental in its training, and teaches the necessity for accuracy, the search of truth, probing error, and the frank acknowledgment of limitations. The gigantic forces set so recently in circulation by the miner and engineer must not only be better understood by the professional man, but also by all leaders of affairs. What is the use of a perfect engineering report, if but hazily and imperfectly understood by those who have to use it?

As to general culture, do the only dumb-bell mental drills of the past, which might be well adapted for a different set of knowledge and economic conditions, hold good when the new economic conditions have revolutionized sciences, wealth, and opportunities of education? Is the average attitude of the students in our great centres

of learning, who so often place athletics and college social success above scholarship, indicative of the satisfying character of knowledge supplied? Never before in the history of the world has there been more necessity for the clearness of vision and honesty of thought than now, when great overwhelming material force is flooding the world. False hopes, false ideals, false education, and revolutionary socialism, which only sees the wrongs and misery of the present, and the cure by annihilation of all good with evil, must be met by sane and strong training of future leaders, and from what schools can we hope to obtain better help than from those of engineering?

Conclusion.— In conclusion, it will be necessary to consider more closely mining as a profession, in which, of course, is included the early stages of metallurgy. The mining engineer must have some sound general knowledge of all other branches of engineering, inasmuch as in the equipment and running of great mines and metallurgical plants he must make use of the training of engineers in almost all the other branches, and to obtain from them their best and hold their respect, it is necessary for him at least to appreciate the foundations of their specialties, intelligently to confer with them, and decide upon merits, rather than dicta.

In addition, he must have special knowledge and training in all pertaining to the discovery, working, and valuation of ore deposits. He must have also sound business experience and judgment to gauge the payability of new ventures, and this in turn requires that he should have had, in some period of his career, a successful experience in management, requiring a knowledge of accounts and faculty of handling men. In distant lands he must have general information of many kinds, and linguistic attainment.

The legitimate uncertainties of mining throw peculiar temptations in his path, as these can be twisted to excuse failures of indolence and unfitness, and also be used as narcotics to conscience when temptation to dishonesty presents itself. His work, especially in metalliferous mining, is often far afield from the observance and guidance of owners or directors, and his work is not of a character that erects lasting monuments or stimulates either admiration or criticism. Thus character, industry, and tact are even greater requisites for true success than brilliancy of intellect.

Right character building, begun in such an institution as this, is

the greatest benefit it can confer. This idea has been most fittingly expressed by one of its most beloved character builders, Professor Kemp, in the *Columbia University Quarterly*, December, 1913.*

It must be a great satisfaction to this University and other kindred training schools for the engineer, to see how the great majority of the students have responded to their character builders, inasmuch as the records of this, and other high-class institutions, show that very few of their graduates have succumbed to gross financial temptation.

Mining brings in touch engineers of different lands with different training, in such a way that general recognition and good fellowship are unstintingly extended (as the speaker must gratefully acknowledge) irrespective of nationality.

Mining as a profession requires varied knowledge and gives scope, ability, and character, and is a profession befitting the true gentleman as well as the adventurous strong man. It affords absorbing and interesting work, and, being basic and productive, extends opportunity for clean money prizes.

Each branch of engineering is based upon metallic foundations; each is dependent upon the other, and none could have reached its present magnitude without the others, but the miner gives to all the other branches the materials that knit them together, in common bond of usefulness, making them effective in the art of "directing the great sources of power in nature for the use and convenience of man."

* "Many follow courses of study in the natural sciences from interest in the subjects, but the student can not do so without reflex influence upon himself. He is, for example, obliged by the very nature of the pursuit to be accurate, precise, and orderly in thinking. False observations, careless records, or confusion of thought bring no results. Clearness and remorseless regard for truth must be all absorbing."

THE MINER AS A PIONEER

BY T. A. RICKARD.

It is a common saying that agriculture and mining are the two basic industries. When man rose above the brutish individualism of his primordial state and began to develop the social instinct, he turned to the soil, in order to win food for his family. He paused in his migration; the soil held him; it gave root to his rudimentary community; it gave him the chance to enlarge his energies. His tracks became highways; his rivers, avenues of trade; and as his traffic expanded, so his imagination widened, until, out of the crudities of communal development grew the complexities of civilization.

But the nomadic habit lingered; the spirit of the hunter survived in man; a wanderer and a wonderer he stood beneath the starry dome of the forest arch not knowing whether he were a guest or a captive in the domain of Nature. The hills beckoned; the seas called; the more venturesome left the tents of the tribe in search of material wherewith to fashion their implements. They sought iron for weapons, copper for tools, gold for ornament, and found them in various guise in the earth under their feet. They became miners. To those who delved successfully came power. Throughout the ages the more energetic and adventurous broke from the plough and forsook the cattle in order to explore and to exploit. They furnished the metals from which the artificers fashioned engines of power and machines of intelligence. They won the materials for a social structure that, based on stone and built in iron and copper, soared in many-storied tracery of steel to towers radiant with light and vibrant to the sky — towers so far above the common ground that man almost forgot his lowly origin and claimed kinship with the stars.

Civilization was developed on a metallic basis, not as regards money, for credit is the expression of an advanced state of society, but as regards implements and instruments, machinery and transport, facilities of living and of communication, all of which required the use of metals. The need of them and the consequent market for them induced enterprising men to probe the hills and scour the deserts in search of the mineral deposits that are distributed with

such perplexing irregularity in the outer crust of the earth. These deposits were not to be found near the smiling cornfield or the gentle hillslope, but in regions where geologic unrest had produced inequalities of contour and ruggedness of aspect, where the surface was bare of soil and the mountains exposed their heart of rock. The miner, therefore, left the sheltered valley and plunged into the outer wilderness. And in his wanderings, he found not only the metallic ore that was the immediate object of his quest; he also discovered new tracts of agricultural land, and new dwelling places for his tribe. Returning home, he told the farmers and shepherds that fertile fields and lusher meadows were awaiting them across the range. They migrated thither, while he again adventured afar across the world, ever pioneering the advance.

This bare outline of a familiar story has already been punctuated by you with memories of the romance that has marked your own national expansion. The story of mineral exploration and racial migration is peculiarly the heritage of our people, the Anglo-Celts. It is the *motif* that runs through the drama of English and American history, more particularly during the last hundred years. Even in its barest outline it serves to suggest that the miner is the pioneer of industry and the herald of empire.

The first social organizations around the shores of the Mediterranean sent their prospectors to the hinterlands of Europe, Asia, and Africa. The gold of Ophir, the copper of Sinai, the silver of Laurium were part of the web and woof of those early civilizations. The mines of Iberia gave Hannibal the sinews of war against Rome, and the gold of Dacia strengthened the resources of Rome under Trajan. But the greatest adventure was that of the Phoenicians who passed through the Pillars of Hercules into the western ocean in order to reach the far Cassiterides, the tin islands that in turn were to produce those Cornishmen to whom this earth is one big mine. After Carthage and Rome, in turn, had been overthrown, the mining industries of the known world were disorganized. Desultory operations persisted in Hungary, Spain, and Saxony, but the Middle Ages to the miner were as dark below ground as above. Even the discovery of America, which marked the beginning of a new world movement, was not connected with a real advance in mineral exploitation, although associated with the gaining of gold

and silver. It is true, the wave of Spanish conquest broke over the American continent, penetrating the treasure-vaults of Mexico and Peru. But the Spaniard devastated, he did not develop. He gathered the harvest that the patient Indian had sown by the laborious toil of centuries. Cortez and Pizarro were filibusters, not explorers; they were pirates, not miners. The *conquistadores* were no pioneers of industry; behind them arose the smoke of ruin and the dust of destruction. Even the great sea-captains of Elizabeth were but the sequel to an epoch of spoliation. After them, and in their wake across the sea, came the men who from Cornwall and Devon, from Saxony and the Harz, brought the technique of mining to the new world, applying it peacefully to the mineral development of Mexico, Peru, and Chile, all along the regions previously ravaged by European freebooters.

But the great era of mineral exploration came with the discovery of gold in Australia and California. It was the prelude to a worldwide migration, an enormous expansion of trade, a tremendous advance in the arts of life, and the spread of industry to the waste places of the earth.

The color of energy began to tint the blank spaces on the map. The western half of the North American continent, all of Australia, the southern half of Africa, the northern half of Asia, were invaded, penetrated, and explored by those in search of gold, or other metals, and as each successive mineral discovery was made by the miner he called upon his fellows to come and take a hand in the good work. He was the scout far ahead of an army of development. Trade follows the flag, it is true, but the flag follows the pick.

Let us recall the story of that odyssey, and see for ourselves what human progress owes to its adventurous forerunners.

First we turn to the American argonauts, the men who sought the Golden Fleece in California. Even the dates in this story are fragrant with romance, for gold was discovered by James W. Marshall on January 24, 1848, and the treaty of Guadalupe Hidalgo, which ended the first Mexican war, was signed on February 2. In other words, California was ceded to the United States 9 days after the great discovery, which, at that time, was not known to either government, fortunately for both of them, and for many

others. Marshall had built a saw-mill for John A. Sutter at Coloma on the south fork of the American river, only 35 miles northeast of Sacramento. When the mill was ready to start, Marshall saw that the tail-race, or ditch leading the water from the wheel, was not deep enough. He proceeded to deepen it by opening the flood-gates to full capacity, so that the swift current would scour the bottom. The water was allowed to run all night. In the morning Marshall noted the effect, and while doing so he saw several yellow nuggets. He hammered one of them, and decided that it was metal; he bit it and found that it was soft; he boiled some of them in a kettle and proved them insoluble in water. Thereupon he went to Helvetia, or Sutter's Fort, to tell his *patron* that he had found gold. Sutter tested the metal with nitric acid, some of which he found among his apothecary stores; he read the article on gold in his copy of the *Encyclopedia Americana;* he weighed the nuggets and compared them with coins; whereupon he also pronounced it gold.

That marked the beginning of the Golden Age in the foothills of the Sierra Nevada. Others found gold in near-by streams; the news traveled to the Atlantic seaboard, and thence to Europe. An excited migration began across the plains, over the Panama isthmus, around Cape Horn. The young, energetic, and adventurous hurried to the Eldorado that promised to fulfil the dreams of Raleigh's day. In 1851 California yielded $81,294,700 in gold. It was no idle imagining, but an astounding fact. Nor does the output of precious metal measure the full consequence of the event. Cities were born, new avenues of commerce were created, the valleys of the Sacramento and the San Joaquin became the granaries of prosperous communities, the unknown territory in the middle of the continent was traversed and explored, the Great West leapt into vigorous life and became an integral part of the American domain. Moreover, among those enriched by the mines were men of initiative and imagination; like Balboa they stood on a peak in Darien; they saw the Pacific and the Atlantic as surely as he did, and to more purpose; they built a transcontinental railroad and tied California to the Union with links of steel.

You may say that most of these adventurers were not miners. I demur. What is a miner? He is the man who does the work of a miner, and that is, to extract ore from the ground. Most of the

young and lusty men that rushed to California had never seen a mine, but that does not matter. They went to do the work of mining, and with the washing of the first panful of gold-bearing gravel they won the badge of Agricola. They had the machinery most used in mining: human muscle; they had the science most approved in that ancient art: organized common sense; they achieved the fundamental purpose of mining: to exploit mineral profitably. They came, they worked, they conquered; and from their labors has arisen a great and glorious commonwealth.

Among those that went to California was E. H. Hargraves, an Australian, who was led by the analogy of geologic conditions to suspect the occurrence of gold in his own country, New South Wales. Returning thither, he was able on April 3, 1851, to inform the Colonial Secretary that gold existed at Lewis Ponds and other localities. He furnished ample proof of his statement, and was suitably rewarded. Hargraves was a man of exceptional intelligence, and the discovery that he made was among the least fortuitous of those that have changed history. It led immediately to search for gold elsewhere in the Australian colonies, then consisting of a few small and scattered settlements along the southeastern coast. In August of the same year a discovery at Buninyong, near Ballarat, started the first big rush to the Victorian goldfields. Sailors left their ships at anchor in Port Philip bay; clerks jumped off their stools to rush to the diggings; every able-bodied man shouldered his blanket and trudged through the bush to engage in the treasure hunt. After all the local population had stampeded, the news reached Europe and incited another economic Hegira. The gold seekers came in ship-loads and they expected to find gold in pailfuls; indeed, many of them were simple enough to believe that gold in quartz meant gold in double pints. They had much to learn, and most of them learned it without delay from the severest of all teachers, *Der Herr Oberbergrat Professor* Experience. In the year 1853 Victoria yielded $54,882,000 in gold.

From the mining-camps eager explorers plunged into the bush, or eucalyptus forest, which, like a sea of perennial foliage, then covered the habitable portions of the Australian continent. Outside them they found the grassy uplands on which the Australian was to grow a later golden fleece, and beyond these pastoral tracts they

invaded the never-never land in which the rivers lose their way. The alluvial mining for gold was the beginning of a new era, it led to the discoveries of tin in Tasmania, of golden ironstone at Mount Morgan, of silver-lead ore at Broken Hill; it started a widespread mineral industry on the island continent; with it came a rapid growth of population of a kind superior to that of the first settlements; agriculture waited on mining, the need for food-stuffs stimulated husbandry, towns arose as if by magic, hastily constructed camps become permanent communities, a new civilization swept the aborigines into the interior, razed the primeval forest, furrowed the soil, cleaved the quarry, built docks, warehouses, and dwellings. Australia was born again. Captain Cook sailed along the coast and placed Australia on a naval chart; Hargraves placed her on the map of the world.

Among the more remarkable explorations of a later day I may instance Western Australia. The interior of that State is an arid plateau; it is the oldest land surface in the globe, and represents the basal wreck of a larger continent. It had been crossed by several parties of explorers, in the hope of finding some oasis in the desert or some outlet of the rivers that fail to reach the sea. In 1887 a discovery of gold was made by Anstey at Yilgarn. This attracted a few prospectors, who scattered farther inland. In October, 1892, Bayley and Ford found a rich outcrop 500 miles from the coast, at Coolgardie. The outcrop was 50 feet long, 6 feet wide, and 5 feet high, spangled with coarse gold. In the March following they sold their claim for £6,000, and a sixth interest. During the ensuing year the new owners extracted 25,872 ounces of gold from 48 tons of ore, which, therefore, averaged 539 oz. per ton. That started the "boom."

Then was seen a strange spectacle. The sandy plain was covered with a monotonous scrub, sparse enough to be traversed easily, yet tall enough to restrict the view and render it easy for the careless to lose their bearings. Many were "bushed," and perished miserably. Emerging from tracts of stunted forest, the gold-seeker found stretches of sand and spear-grass or else shallow depressions with clay bottoms from which the mirage lured him to unslakable thirst. Water was scarce, and uncertain at the best; a new peril faced the miner; early in the development of this region he learned

to dig a hole to salt water and distill the brine in a rough apparatus. But a lack of the prime necessity of life was a grim factor in the search for gold.

With the whisper of each new discovery, crowds of reckless men plunged into the outer desolation. Eager horsemen jostled those on awkward camels, whose swinging gait carried them past the mob of diggers trudging wearily forward. The incident known as the Siberia rush is typical of those days. The name Siberia is a biting satire, for the temperature is that of Tophet. A man came into Coolgardie one night with a story that gold had been found at a spot 30 miles to the north. The rumor vibrated like wireless telegraphy through the tents and corrugated iron shanties. Quietly one arose and another followed. Scores started on horses or on camels; hundreds went on foot, carrying their "billies" and blankets on their shoulders or trundling their packs in wheelbarrows. Some took the wrong direction, and of these many lost their way and died miserably in the bush. Four hundred reached the scene of discovery. The only water available was in a "soak" or water-hole seven miles distant. It was soon drained dry by the thirsty diggers. News came to Coolgardie that a water famine was imminent. A government official promptly dispatched a dozen camels bearing water to the succour of the adventurers. In the meantime, most of them, aware of the danger impending, had started to reach the nearest "condenser" or distillation plant. Many died on the way, and many more would have perished save for the water brought by the camel-train. Nevertheless, in a few days there was another stampede in another direction. Thus the goldfield was explored. *Sic Etruria crevit.*

We go next to South Africa. The Phoenicians sailed round it; the Portuguese landed on its shores; the Dutch founded sundry little settlements; but it was the finding of diamonds and gold that proved the "open sesame" to the portals of the Dark Continent. Dutch hunters had roved northward from the Cape to the Vaal and the Orange; later Boers had trekked beyond both of these rivers; but none among them had imagined that diamonds were mingled with the pretty garnet, jasper, and agate pebbles bordering the stream. In 1867, in the hamlet of Hopetown, a child found a shining stone and played with it. The mother gave it to a Dutch

neighbor, and he in turn asked an Irishman to ascertain what it was. But no one thought it worth anything until a local official noted that it scratched glass. Thereupon it was sent to a mineralogist, who did not hesitate to label it a diamond. But it led to nothing. No others like it were found immediately in the same locality. In March, 1869 — two years later — a Griqua shepherd found a magnificent diamond near the Orange river; it weighed 83½ carats, and was sold by him for 500 sheep, 10 oxen, and a horse. Subsequently, it brought £25,000, and became known as "the Star of South Africa." Indeed, it was the dawn of a new era. With that discovery began a great rush to the banks of the Vaal. At first from the neighboring parts of South Africa and then from every quarter of the globe there thronged a motley mob of fortune-hunters. The majority were men of British descent, but even the stolid Boers were attracted, every European nation was represented, and with them all shades of black and brown, from the undiluted negro to the mezzotint half-breed. To all of these the winding shallows of the Vaal were as the valley of Sinbad the Sailor.

Meanwhile, bigger discoveries had been made on the farmlands of the Dutch squatters, for it had been proved that the distribution of the gems was not restricted to the alluvium of the river flats, but extended through the surface soil and calcareous cement into the yellow and blue ground constituting the matrix of the diamond. Of these mines, the Kimberley and De Beers were the most important, and on their development hinged events of historic significance.

Among those attracted to the diggings were two remarkable men: an Oxford student named Cecil John Rhodes and a young Hebrew from London called Barnett Isaacs, famous later as Barney Barnato. One became identified with the De Beers, and the other with the Kimberley mine. Both of them saw that consolidation was imperative if the diamond market was not to be glutted. They fought strenuously for control; and Rhodes, backed by Alfred Beit, won. On July 18, 1889, the deal was closed by a cheque for £5,338,650, which was the price of the Kimberley mine. Since then the De Beers Consolidated has distributed £30,000,000 in dividends, and redeemed debentures to the value of £4,822,705.

Kimberley became a distributing point for the adjacent mineral region. In 1884 the De Kaap goldfield was discovered, whereby the districts of Barberton and Pilgrim's Rest came into existence. In 1885 Laurenz Geldenhuis found gold in shale on the hills north of the farm Roodepoort. Later in the same year Arnold detected gold in conglomerate lying on the farm Langlaagte. Both of these finds were made on the Witwatersrand or White Waters range. In December, Harry Struben, who had learned something of mining at Kimberley and Pilgrim's Rest, erected a 5-stamp mill, and with that the exploitation of the Rand may be said to have commenced. On July 18, 1886, the goldfield was proclaimed. The sober veldt sprang into busy life, and the greatest gold-mining industry of the modern world came into being. In the next 25 years the Rand produced £309,872,000 worth of gold, the maximum annual output being in 1912, when it was £37,182,795 from 25,486,361 tons of ore.

Rhodes and his partners participated in that development, but the diamond discoveries had an even wider influence, for they provided capital and energy for the extension of industry into the very heart of Africa. This brings us to the story of Rhodesia.

It was the ambition of Rhodes, always backed generously by Beit, to paint the map red. He worked and schemed to found a new empire in the northern hinterland — a word of which Rhodes was particularly fond. At that time German and Portuguese colonial expansion seemed likely to absorb the vast interior made known by the explorations of Livingstone and Stanley. This threatened the future of that South African Union which Rhodes had in mind. By obtaining a concession from Lobengula, chief of the Matabele, who dominated the weaker tribes, he got a foot-hold. With this, in 1888, he incorporated the British South Africa Company, under royal charter, and by the purchase of concessions obtained by other adventurers, he consolidated a great tract of grazing and mining territory under the British flag.

Two years after the Chartered Company was formed, a military expedition was sent by Rhodes to Mashonaland, the southern part of this new country, to cut a road through the bush for 430 miles, from Tuli to Salisbury, which was founded on September 12, 1890. The members of this expedition, having accomplished their task peaceably, disbanded and went to work as prospectors. They un-

covered the mines of the Gatooma district. In this case the discovery was not made in the usual way by tracing the gold of the river-bed or the detrital quartz on the hillside to its source in a vein or lode. The prospectors were guided by ancient workings, made by a forgotten people, probably of Arabian origin. And though the first operations were not successful, owing to lack of transport and supplies, they laid the foundation of a prosperous business. The men who did this work were preëminently the pioneers of industry; they were actually enlisted as the Pioneer Corps; they were guided by a famous elephant hunter; they were commanded by a mining operator, now chairman of several London companies; the rank and file included a large number of men familiar with mining at Kimberley and Johannesburg. Literally, they prepared the way for others, and started the mineral exploration that opened the interior of South Africa to orderly development and civilized habitation from the Cape of Good Hope to the sources of the Nile.

West Africa as a mining region is identified historically with the Gold Coast, a traditional source of wealth. Herodotus speaks of the Carthaginians as receiving gold from native tribes that traded with wild people on the west coast of Africa. During the medieval period Europe obtained most of its scanty imports of gold from this source. Successive traders made an effort to lay hands on the legendary treasure of the region. But they proved abortive. A malarial shore and a dense jungle blocked the passage of the white man. Nevertheless, during the earlier half of the 19th century the export of gold is estimated to have averaged £350,000, or $1,750,000 per annum, all of it the gleanings of native workers. Not until 1880 did real mining begin, on the initiative of an intrepid Frenchman, Marie Joseph Bonnat. An orphan, first a shoeblack and subsequently a *chef* in a Paris hotel, he met there two ivory-hunters to whom he offered his services for one year without pay. He was engaged, and went with them to West Africa. When they retired from business, two years later, they bequeathed their equipment to him. Thereupon he went into business on his own account. On one of his ivory-hunting journeys he was captured by the Ashantis and remained a prisoner in the king's kraal for three years, until released by Sir Garnet Wolseley, in 1874, on the occasion of the Coomassie campaign. While a captive he saw the king's treasures

of gold and heard of the diggings on the Tarkwa range. When liberated, he obtained a concession from the king of Eastern Wassau, and returned to Paris, where, in 1877, a company called the Côte d'Or was organized by him to operate the mines now known as the Taquah and Abosso. Forthwith other traders obtained concessions and took them to London, where two or three companies were formed. But these early enterprises did not prosper. As was the case in Rhodesia at first, the lack of transport, the scarcity of supplies, and sickness among the pioneers crippled operations. Bonnat himself did not live to see the fruit of his labors; he died at Taquah in 1881. His was a gallant spirit worthy of rank among the best of the heroic forerunners of civilization.

As a sequel to gold mining in West Africa came the clearing of the bush, the training of the natives, the building of a railway, and the introduction of sanitary reforms. Then followed the finding of tin on the highlands east of the Niger, where now a thriving industry is established. This, in turn, has admitted light and air into the tropical jungle, facilitated the establishment of cocoa, rubber, and cotton culture, and brought a dark corner of the earth within touch of the vitalizing forces of industrial progress.

And now, for our last illustration, we go to Canada. The story of the Yukon is so recent as only to need recalling. That remote corner of the North American continent was slow to be unveiled. The mountains guarding the coast discouraged the Russians who crossed the sea from Kamchatka; the main range barred the way of the English fur-traders and French *voyageurs* who came overland. In 1843 the Russian Zagoskin ascended the Yukon as far as the Tanana, and about the same time Robert Campbell, an agent of the Hudson's Bay Company, descended the river to its confluence with the Porcupine. But the only object of these intrusions into the inhospitable wilderness was the trade in furs. No whisper of gold was heard.

The first gold to come from the Yukon consisted of two nuggets obtained from an Indian in 1880. Small parties of prospectors began to test the creek-bottoms. Encouraging discoveries were made, but none of them was remarkable; moreover, the precarious food supply and the shortness of the season checked enthusiasm. In 1896 the annual output of gold was about $1,000,000, of which

only $300,000 came from Canadian territory, for the more productive diggings were on the Alaskan, or American, side of the boundary, which is about 50 miles below Dawson, where the waters of the Klondike mingle with those of the Yukon. Up to that time this vast watershed was of no particular consequence as a mining region. Then suddenly, out of a clear sky, came the tremendous shout of a great gold discovery.

On July 14, 1897, the steamship *Excelsior* arrived at San Francisco, bringing miners laden with sacks of gold. They told stories of a new Eldorado in the North, in the valley of the Klondike, on the edge of the Arctic. Again the world heard the bugle-call of adventure. The response was instant. During the following winter 33,000 people landed at Skagway on their way to the Klondike. An eager procession climbed the passes that led over the coast range to the headwaters of the Yukon, down which they voyaged in boats and rafts to Dawson. The horrors of that scramble are almost forgotten. Men, and women also, devoid of experience, physically unfit, laden with packs, toiled up the long ascent in a frenzy to lay hands on the gold. Before this mob reached the diggings the richest ground had been located by the miners and traders previously in the country. Yet some of the newcomers also fared well. The romance of the rush was not with the luckless wastrels, the greedy courtezans, or the drunken desperadoes, but with the quiet strong men who greatly endured and nobly overcame the trials of an unaccustomed life, and returned home to become leaders in a peaceful community.

In 1898, the Klondike yielded $10,000,000, and in 1901, $22,000,000. The total output so far has been $150,000,000.

The story of the discovery remains to be told. In the summer of 1896 Robert Henderson, a Nova Scotian, who had mined in Colorado, found gold across the divide from the Klondike. At this time George Carmack, a squaw man, being short of fresh meat, went up the valley of the Klondike in search of moose. Two Indians went with him. Turning up one of the tributary creeks, they worked their passage through the thick underbush and the thicker mosquitoes until fatigue necessitated a halt. While resting, the two Indians panned the gravel and found gold. Crossing the divide, Carmack and his Indian friends visited Henderson's camp, but they

said nothing to him about their discovery, for he showed a dislike of Indians. Returning, they found more gold on the same creek, now famous as Bonanza. Thereupon, Carmack and each of the Indians located a claim. That was on August 17, 1896. Putting the gold they had panned into a cartridge-shell, they hastened down the Yukon to Forty-mile, which was the nearest recording office.

This event opened a new province to human industry. Within a couple of years big steamers were ploughing the waters of the Yukon, a railway had been constructed over the coast range, the telegraph had linked the northern frontier with the nerve centres of the world, and new communities had arisen in the very heart of a vast solitude. It was not long before agriculture was started close to the Arctic circle and children played where lately moose and caribou had roamed at will. Once more, the miner had started the springs of life and called a new world into being.

Other examples of pioneer work might be instanced, did time permit. You will have noted that the lure of gold was the incentive to most of these explorations. The reason is obvious. Gold is a metal occurring in nature in a nearly pure state; in its alluvial form it is readily separable from the river gravel; and even from its matrix in the rock it is extracted by easy methods. Moreover, it commands a high price, and a free market, so that it can be transported in small bulk and sold in unlimited quantity. Gold mining, therefore, has been the prelude to the exploitation of the base metals existing in complex ores. The simple operations of the gold miner have preceded the establishment of economic conditions favorable to the more complicated business of winning the other metals.

The British empire and the American commonwealth alike have advanced in the track of the miner. He made the Great West a part of your heritage; he conquered the Overseas Dominions more truly than the soldiers of the King. The curtains that hid Central Africa were parted momentarily by the slave-trader, the elephant hunter, and the missionary, but when these emerged those curtains closed again. It was left to the miner to place his candle so that like "a good deed in a naughty world" it might illumine a path for human industry. The primeval forests, the sunlit valleys, and the grassy plains of Australia remained as they were in the morning of time until the prospector called for his own people to come thither

across the sea. The fur-trader traversed the snow-clad plains and penetrated the pine-clad mountains of the Canadian Northwest; the salmon-fisher sailed into the long estuaries; but neither of them touched the heart of that great lone land. Not until the pick of the miner awoke echoes that had slumbered since creation did the vast solitude respond to the pulsations of human endeavor. Hunters, traders, even soldiers and farmers, crossed the prairies from the Mississippi to the Rocky Mountains, and adventured over the desert to the Pacific Coast. They carried the flag, and they hoisted it over the new dominion, but it was an empty conquest and a vain annexation until the miner spoke the word that set the world aflame.

After the prospector has come the mining engineer. The scout has gone in advance of the captain of industry. Those of you that have crossed the range in winter know how the leader breaks the trail by leaving foot-prints into which his followers tread, step by step, greatly to the safety and ease of their travel. That is what the mineral explorer has done for the mining engineer. That is what the mining engineer has done for those behind him. Some of you have been prospectors as well as engineers.

"Have you known the Great White silence, not a snow-gemmed twig a-quiver?
"Have you broken trail on snowshoes; mushed your huskies up the river?
"Have you marked the map's void spaces,
"Felt the savage strength of brute in every thew?"

Again, I ask you to recall how you threaded the pathless forest on your way to examine a new mineral discovery. On the trees at intervals you have seen that the bark was chipped. The trail has been "blazed" by the prospector, making it easy for you and others to follow. That is what the miner has done in a larger way for civilization. He has done it with geographical exuberance and equatorial amplitude. From the "the stark and sullen solitudes that sentinel the Pole" to the "steaming stillness of the orchid-scented glade" in the Tropics, he has left his mark. You know that. No need for the prospector to complain to you, like Kipling's explorer:

"Well I know who'll take the credit; all the clever chaps that followed—
"Came a dozen men together—never knew my desert fears;
"Tracked me by the camps I'd quitted, used the water holes I'd hollowed.
"They'll go back and do the talking. They'll be called the Pioneers!"

No; not by the men of the Columbia School of Mines, who have shared the prospectors' camp-fire, his blankets, his flapjacks, his bacon and his beans. You will give credit to whom it belongs. To the man with the faith of a child and the heart of a Viking, to the man who has tramped and toiled until he heard "the mile-wide mutterings of unimagined rivers and beyond the nameless timber saw illimitable plains"; to the miner who has crossed the last range of all and lies in the only prospect-hole he could not dig; to the man who was the herald of empire and the pioneer of industry; to him who blazed the trail.

PRESIDENT BUTLER.— It had been our expectation that the candidates for these high honors would be presented by the revered teacher of each one of them, John Howard Van Amringe, Professor Emeritus of Mathematics. The overwhelming sorrow that has recently fallen upon his household deprives us of the privilege of greeting him in person, but our deep, affectionate sympathy, born of a half century's contact with him, goes out to him at this moment. In his absence the candidates for honorary degrees will be presented by William Barclay Parsons, of the Class of 1882, Chairman of the Committee on Honors of the Trustees of Columbia University.

WILLIAM BARCLAY PARSONS.— It is a source of deep regret to everyone of us that Dean Van Amringe is not with us to make the presentation of candidates for honorary degrees, but I assure you that you are quite right that in this hour of his bereavement the deep and heartfelt sympathy of the graduates of the School of Mines is "Van Am's" to-day. Although, sir, he cannot be with us in person, nevertheless he has been good enough to write out the words he would have said had he been here, and that message I will now read to you.

Mr. President: Fifty years ago, when this Nation was in the throes of a mighty and destructive civil war, the School of Mines, of Columbia College — to use the title of that day — was instituted, with the intent of supplying to the country, for the economic utilization of its mineral resources, men versed in the principles of mining and metallurgy and qualified to apply them. The need of the time for mining engineers and metallurgists was great, and the success of the enterprise immediate. During the half century which has since elapsed, the School has increased the number of its professional courses, and, by having in each of them, from the beginning and throughout, a definite aim and following it with exceeding care and thoroughness, early became, and has continued to be, in ever growing measure as its scope widened, a beneficient and potent agent in the dissemination of sound scientific learning, of solid professional acquirement, of skilled methods in developing the material

resources of nature, of new scientific truth and, through the character of its graduates, of the influences that tend to improve the art of living and promote the general welfare of society.

PROFESSOR J. HOWARD VAN AMRINGE.

In commemorating the rise and progress of such a school, nothing could be more fitting and impressive than that the University should single out graduates of exceptional merit, and put upon them, publicly and ceremoniously, the mark of its approval and hearty commendation. Therefore, it is, sir, that I have the welcome

SCHOOL OF MINES, SECOND PERIOD. SOUTHWEST CORNER 4TH AVE. AND 50TH ST.

duty of presenting to you, for the honorary degrees of Master of Science and Master of Arts, this company of scholars and practical men of science, of notable achievement in their respective professions — men who, as chemists, geologists, metallurgists, engineers, architects, investigators, inventors, teachers, authors, have added to the sum of knowledge in the specialties to which they have severally

HAMILTON HALL, LOOKING SOUTHEAST FROM CORNER MADISON AVE. AND 50TH STREET.

devoted themselves, have had their full share in making new and advantageous applications of fundamental principles, in multiplying the uses of electricity and in creating the science and the profession of electrical engineering, in robbing hazardous processes of much of their danger and ameliorating the conditions of large numbers of workmen, in heightening the prosperity of the country by converting wastage in mines and their products into profit; men who direct great industries through the authoritative positions which they have acquired by the exhibition of superior technical knowledge and efficiency, who enhance the comfort, the grace and the dignity of human life, by contributing to its safety and convenience, to the beauty

of its environment, to a revelation of the secrets of nature, to an appreciation of "Nature's unchanging harmony," to an understanding of the myriad voices of the Earth.

They richly deserve the approbation of their *Alma Mater;* and I beg that you will now signalize this commemoration day by conferring upon them, *honoris causa,* the degrees which have been gladly accorded them.

JOHN ADAMS CHURCH.— Engineer of Mines, of the Class of 1867. A member of the first class to be graduated from the School of Mines, with a long record of distinguished service in his profession.

WHEATON BRADISH KUNHARDT.— Engineer of Mines, of the Class of 1880. An authority on steel processes and magnetic separation of ores.

CARL AUGUST MEISSNER.— Bachelor of Philosophy, of the Class of 1880. For more than thirty years at work upon improvements in the manufacture of iron and steel, a chief authority on the manufacture of coke.

ARTHUR HENRY ELLIOTT.— Bachelor of Philosophy, of the Class of 1881. One of the earliest and most active graduates of Columbia to take a prominent part in the development of the gas industry.

FRANCIS BACON CROCKER.— Engineer of Mines, of the Class of 1882. An inventor, teacher, and director of research, unselfish in pursuit of the highest scientific aims and of public service.

JOHN PARKE CHANNING.— Engineer of Mines, of the Class of 1883. A chief authority on copper mining, with a record of exceptional courage and skill in the development of large porphyry deposits.

ROBERT VAN ARSDALE NORRIS.— Engineer of Mines, of the Class of 1885. Taking a leading part in the development of coal mining and in the solution of its scientific and practical problems.

ARTHUR SMITH DWIGHT.— Engineer of Mines, of the Class of 1885. Inventor of a metallurgical process of the highest value in the conservation of products heretofore wasted, and greatly increasing the safety and health of men engaged in work on lead processes.

RUDOLPH PHILIP MILLER.— Civil Engineer, of the Class of 1888.

Superintendent of Buildings for the Borough of Manhattan, and exercising a strong influence in drafting and codifying the building laws.

FREDERICK WARNER DENTON.— Civil Engineer, of the Class of 1889. Successful alike as a teacher of mining engineering and as a practising engineer.

KARL EILERS.— Engineer of Mines, of the Class of 1889. With a reputation for skillful scientific and practical work in the metallurgy of lead and silver.

GANO DUNN.— Electrical Engineer, of the Class of 1891. Former President of the American Institute of Electrical Engineers, with a notable record of scientific and practical achievement.

PRESIDENT BUTLER.— I gladly admit you to the degree of Master of Science in this University, and confer upon you all the rights and privileges that belong thereto; in token whereof, I hand you these diplomas.

HENRY FREDERICK HORNBOSTEL.— Bachelor of Philosophy, of the Class of 1891. Constantly showing fine imagination, boldness. and ingenuity in the solution of large architectural problems.

GOODHUE LIVINGSTON.— Bachelor of Philosophy, of the Class of 1892. With a long record of successful achievement in the profession of architecture.

PRESIDENT BUTLER.— I gladly admit you to the degree of Master of Arts in this University, and confer upon you all the rights and privileges that belong thereto; in token whereof, I hand you these diplomas.

PRIZE POEM.

BY RHYS CARPENTER, 1909.

COLUMBIA

Serene upon thy citadel,
  Above a city's dark unrest
Holding thy watch immutable,
  Unvexed, unsaddened, undistressed;
The changeless symbol of a creed,
  Too great for party or for sect,
To heal a people in their need
  Lest manhood perish for neglect.

O mother of a mighty nation,
  O guardian of our liberty,
Through changing year and generation
  Thy sons come ever unto thee,
With eager hearts, and quick desire
  Beneath ambition's glowing sun
To kindle at thy quenchless fire
  The light with which their race is run.

They leave thee, and are scattered far
  On prairie waste and golden plain,
And where the Western mountains are
  They guide the nation's toil and gain;
Deep under earth in torches' glare,
  Or where the flaming forges reel,
Where rings mid furnace roar and flare
  The clangor of the shaken steel;

Where famine breaks, where plague and ill
  Rears up its hundred-headed form;
Where strife has taught mankind to kill,
  And wars unloosed their dreadful storm —
Throughout the great earth's restless length
  Thy sons are gone, and in their hands
Thy lore has set a rod of strength
  Wherewith to dominate all lands.

INAUGURATION OF CHANDLER LECTURESHIP.

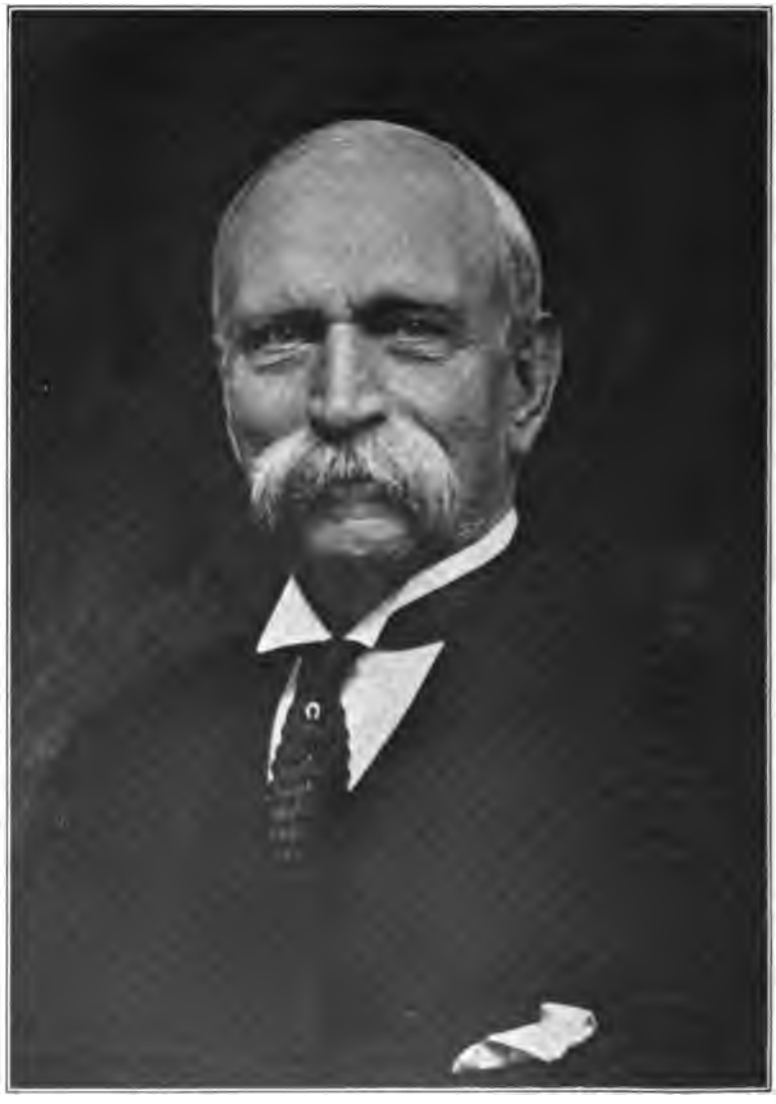
Introductory Address by Professor Emeritus Chandler

It is a proud moment for me to see representatives of every class for the last fifty years gathered here to-day, men of all ages, some with gray hair, some part gray, and some of all colors, all come back here to celebrate the fiftieth anniversary of the School of Mines. But that fifty years has been all too short. I don't believe any one has ever had a happier life than I have had — congenial occupation and association with earnest young men, every one of whom is anxious to be something and to do something, and to have had the pleasure of helping them do it. If Saint Peter were to give me an opportunity to "come back" some day and make another trial of it, I would like to live it all over again on the same lines as I have done, to do the same old things but to do them better, if I could.

My memory has been running back to-day to the men to whom we owe the School of Mines. There is no reason to suppose that the School of Mines would be in existence to-day if it had not been for the efforts of Dr. Egleston and his colleagues. At the time it was founded, no school of mines existed in the United States, and New York City was thought to be the last place in the world one would select to establish such a school as Egleston had in mind. Everybody ridiculed the idea of starting such a school here, and even after it opened, with great promise of success, everybody said it wouldn't last a year. The "Plan for a School of Mines and Metallurgy in New York City, by T. Egleston," which was printed in 1863, attracted the attention of some of the trustees of Columbia College. The Smithsonian Institute had been offered the project, and they thought it was out of their line. Peter Cooper considered the matter and said, "Why, Egleston, you propose to give a great deal of education to a small number of men. The scheme of the Cooper Union is to give a moderate amount of education to a large number of men. The two schemes are diametrically opposed to each other. You can't fit the School of Mines into Cooper Union."

At the time of the founding of the School of Mines, Columbia College was land poor. The city had refused to give Columbia

$10,000, although it was giving large sums of money to other institutions. Finally they said, "There's that old Botanical Garden.



PROFESSOR CHARLES F. CHANDLER.

You can have that." The Columbia authorities said, "What's the use of that; it will never be of any value to us?" One of the wiser

heads said, "You had better take it." So they took the Botanical Garden, which began at 50th Street and extended four blocks up

COLUMBIA COLLEGE ABOUT 1860. CORNER 49TH ST. AND MADISON AVE.

Fifth Avenue. At that time it was entirely unproductive; it had rock above the level of the street. The college borrowed $400,000

and put houses on the land as an inducement for people to occupy it. But they would not start the School of Mines. Finally they said to Dr. Egleston, "If you can start your School of Mines without asking us for any money, and if you are willing to take the professorship without a salary, and if you can find some other fellows to do the same, if you can find any empty rooms in our building at 49th Street you may take possession of them."

Now, Dr. Egleston was an old New Yorker and knew a great

FIRST SCHOOL OF MINES BUILDING, LOOKING WEST ACROSS NEW YORK CENTRAL TRACKS AT 50TH ST.

many men in the city, some of whom he was fortunate enough to interest in his project. I want to mention the names of the men to whom we owe the School of Mines. Many of you have never heard of them; many of you think that this School of Mines sprang into existence without any work on anybody's part. Among these gentlemen, these trustees, George T. Strong took a most active interest in it. Samuel B. Ruggles, Hamilton Fish, Lewis M. Rutherford, and Dr. Torrey were among the most active members of the trustees in this enterprise. They listened attentively to what Dr. Egleston proposed, and thought they saw promise in it; they enlisted the services of nearly twenty gentlemen, who were not trustees but

were afterwards made associate members of the Committee of Trustees on the School of Mines. There were Agnew, Anthon, Bridgham, Delafield, Delano, Dodge, Foster, Hosack, Kennedy, Prime, Tuckerman, Swan, Potter, Ostensacken, and Ward, as associate members. Those were the men who furnished the money to enable Egleston to start the School of Mines.

There wasn't much to start with; we didn't think it necessary to ask for much. We fitted up tables for 12 students in the basement

FIRST SCHOOL OF MINES BUILDINGS, LOOKING SOUTHWEST FROM CORNER 4TH AVE. AND 50TH ST.

of an old broom factory. Dr. Barnard in the meantime had been appointed President of Columbia College, and he took a most lively interest in it. The first day, to the surprise of everybody, 24 men made their appearance, and entered the School of Mines; that was the 15th of November, 1864. We had thought that if we had 12 pupils it would make a very good beginning for the first year, and were greatly surprised and much gratified to find double that number the day we opened the school. So we took heart and renewed courage and immediately sent out for a plumber and a carpenter to put up more tables and increase the accommodations. The next day more pupils came, and the following days we had more carpenters

and more students alternately until there were 47 students the first Winter. And a debt of $6,000 to boot! We were absolutely ir-

LIBRARY ON 49TH STREET, LOOKING EAST.

responsible. Really the only financially responsible person was Professor Egleston.

I should not forget to tell you this School of Mines is designed on the plan of the École des Mines, of Paris. Egleston and Vinton

graduated together in 1860 from this Paris School of Mines. Egleston was a Yale man, and Vinton was from West Point. Dr. Haight, a member of the Trustees, took a lively interest in the School of Mines; he said, "It looks very much as though we have had a child born in Columbia College. We must clothe it and provide for its maintenance." So when we had run in debt and borrowed $10,000 he paid our debt and gave us $4,000 to see us through the first year.

The trustees took a keen interest in the School of Mines and did everything they could for its success; they saw that something must be done to provide more room. It so happened that on these grounds was a four-story building which had been occupied as a workshop by deaf mutes, and was rented as a broom factory. This building they turned over to us and gave us $10,000 to fit it up; so we installed a laboratory and fitted up a drawing-room for Vinton's pupils. As soon as the college professors saw that the School of Mines really meant something, and was going to be a success, they promptly hurried over to say that they were ready to do anything for us. Professor Van Amringe offered to teach mathematics, and Professor Peck mining surveying; Rood said he would teach physics. Professor Joy, whose assistant I had been at Union College until he had gone to Columbia, and whose successor I was, said he would not stay out of the School of Mines; so I told him to take whatever portion of the chemical instruction he wanted and I would take the rest. We fitted up the place, arranged for 72 students, and, to the surprise of everybody, 89 made their appearance.

At the end of the second year the College had spent $30,000 on us, and the enterprise was so promising that they could not find room to put us; so they offered us $30,000 to put up a building on Fourth Avenue. We had no architect to advise us, and didn't dare engage one, for two reasons. In the first place, five percent. commission seemed too large a sum; and, in the second place, we wanted a laboratory that would be suitable for chemical purposes (Laughter and applause). That seems to amuse you, but I have had some experience along that line. My brother built a laboratory at Lehigh University, and his architect said, "I don't know anything

about a chemical laboratory, but if you will tell me what you want I will carry out your ideas and build such a building as you need."

INTERIOR OF 49TH STREET LIBRARY.

That was the most sensible architect I ever heard of.

So we built our $30,000 building, but we had no geologist. I had

been pretending to be a geologist and had been giving lectures on geology, having had a good teacher. We were advised to get Newberry; he was a host in himself and added greatly to the prestige of the School of Mines. He took the upper story of the Fourth Avenue building and put in his wonderful collection of fossils, rocks, and minerals, and in the third year the School of Mines was established, to last forever.

When I retired, three years ago, everybody connected with Columbia did all in his power to honor me, flatter me, and make me very happy in my retirement. Among the various things they did to keep my memory green, for which I shall always be grateful, was to establish the Chandler Lectureship, which they tell me is to last forever. Every year a distinguished scientist is to be invited to deliver a lecture, and the punishment he is to get for it is a gold medal with my effigy on it. Nothing could give me greater pleasure than to know that on this occasion the first lecture is to be delivered by my old friend, Dr. Leo. H. Baekeland.

As some of you are not so well acquainted with him as I am, I wish to say a word or two before I introduce him. He graduated at the University of Ghent as Bachelor of Science in 1882. He continued his studies there, and in 1884 passed his examination with the highest grade, getting the degree of Doctor of Science. He then entered the competition for Laureate. It seems that this contest is open only to Doctors of Science, and the jury appointed to pass upon the merits of the candidates is composed of the highest men of science in Belgium. The fortunate candidate, who is supposed to have spent three years in original investigation, receives a Laureate which carries with it a three-years' travelling scholarship. Dr. Baekeland won it, and spent several years travelling in England, Scotland, the United States, and Germany, in the study and investigation of chemical subjects. Later he was made Professor of Chemistry and Physics of the Government Normal School in Bruges. Then he was made Associate Professor of Chemistry at the University of Ghent. In 1890 he came to America where he has distinguished himself by the originality of his investigations and the remarkable inventions which he has made, based on chemical principles, the latest of which is the wonderful substance named baekelite in honor of the inventor.

I now introduce to you Dr. Baekeland. (Applause.)

SOME ASPECTS OF INDUSTRIAL CHEMISTRY.*

BY LEO H. BAEKELAND, SC.D.

While I appreciate deeply the distinction of speaking before you on the occasion of the Fiftieth Anniversary of the Columbia School of Mines, I realize, at the same time, that nobody here present could do better justice to the subject which has been chosen for this lecture than the beloved master in whose honor the Charles Frederick Chandler Lectureship has been created.

Dr. Chandler, in his long and eminently useful career as a professor and as a public servant, has assisted at the very beginning of some of the most interesting chapters of applied chemistry, here and abroad. Some of his pupils have become leaders in chemical industry; others have found in his teachings the very conception of new chemical processes which made their names known throughout the whole world.

Industrial chemistry has been defined as " the chemistry of dollars and cents." This rather cynical definition, in its narrower interpretation, seems to ignore entirely the far-reaching economic and civilizing influences which have been brought to life through the applications of science; it fails to do justice to the fact that the whole fabric of modern civilization becomes each day more and ever more interwoven with the endless ramifications of applied chemistry.

The earlier effects of this influence do not date back much beyond one hundred and odd years. They became distinctly evident during the first French Republic, increased under Napoleon, gradually spread to neighboring countries, and then reaching out farther, their influence is now obvious throughout the whole world.

France, during the revolution, scattered to the winds old traditions and conventionalities, in culture as well as in politics. Until then, she had mainly impressed the world by the barbaric, wasteful splendor of her opulent kings, at whose courts the devotees of science received scant attention in comparison to the more ornamental artists and belles-lettrists, who were petted and rewarded alongside of the all-important men of the sword. In fact, as far as the culture of science was concerned, the Netherlands, Germany, and

* This lecture is printed in pamphlet form by the Columbia University Press, New York.

Italy, and more particularly England, were head and shoulders above the France of "le Roi Soleil."

If for no other reason, France needed scientists to help her in her wars against the rulers of other European nations. She needed them just as much for repairing her crippled finances and her badly disturbed industries which were dependent upon natural products imported until then, but of which the supply had suddenly been cut off by the so-called continental blockade. Money-prizes and other inducements had been offered for stimulating the development of chemical processes, and — what is more signficant — patent laws were promulgated so as to foster invention.

Nicolas Leblanc's method for the manufacture of soda to replace the imported alkalies, Berthollet's method for bleaching with chlorine, the beet-sugar industry to replace cane sugar imported from the colonies, and several other processes, were proposed. All these chemical processes found themselves soon lifted from the hands of the secretive alchemist or the timid pharmacist to the rank of real manufacturing methods: Industrial chemistry had begun its lusty career.

First successes stimulated new endeavors and small wonder is it that France, with these favorable conditions at hand, for a while at least, entered into the most glorious period of that part of her history which relates to the development of chemistry, and the arts dependent thereon.

It is difficult to imagine that, at that time, Germany, which now occupies such an enviable position in chemistry, was so far behind that even in 1822, when Liebig wanted to study chemistry at the best schools, he had to leave his own country, and turn to Gay-Lussac, Thénard and Dulong in Paris.

But the British were not slow to avail themselves of the new opportunities in chemical manufacturing so clearly indicated by the first successes of the French. Their linen bleacheries in Scotland and England soon used an improved method for bleaching with chloride of lime, developed by Tennant, which brought along the manufacture of other chemicals relating thereto, like sulphuric acid and soda. The chemical reactions involved in all these processes are relatively simple, and after they were once well understood, it required mainly resourceful engineering and good commercial abilities

to build up successfully the industries based thereon. From this epoch dates the beginning of the development of that important industry of heavy chemicals in which the British led the world for almost a century. In the same way, England had become the leader in another important branch of chemical industry — the manufacture of coal-gas.

The Germans were soon to make up for lost time. Those same German universities, which, when Liebig was a young man, were so poorly equipped for the study of chemistry, were now enthusiastically at work on research along the newer developments of the physical sciences, and, before long, the former pupils of France, in their turn, became teachers of the world.

Liebig had inaugurated for the chemical students working under him his system of research laboratories; however modest these laboratories may have been at that time, they carried bodily the study of chemistry from pedagogic boresomeness into a captivating cross examination of nature. And it seemed as if nature had been waiting impatiently to impart some of her secrets to the children of men, who for so many generations had tried to settle Truth and Knowledge by words and oratory and by brilliant displays of metaphysical controversies.

Indeed, at that time, a few kitchen tables, some clumsy glass-ware, a charcoal furnace or two, some pots and pans, and a modest balance, were all that was needed to make nature give her answers. These modest paraphernalia, eloquent by their very simplicity, brought forth rapidly succeeding discoveries. One of them was truly sensational: Liebig and Wöhler succeeded in accomplishing the direct synthesis of urea; thinking men began to realize the far-reaching import of this revolutionary discovery whereby a purely organic substance had been created in the laboratory by starting exclusively from inorganic materials. This result upset all respected doctrines that organic substances are of a special enigmatic constitution, altogether different from inorganic or mineral compounds, and that they could be built up only by the agency of the so-called "vital force" — whatever that might mean.

Research in organic chemistry became more and more fascinating; all available organic substances were being investigated one after another by restless experimentalists.

Coal-tar, heretofore a troublesome by-product of gas manufacture, notwithstanding its uninviting, ill-smelling, black, sticky appearance, did not escape the general inquisitive tendency; some of its constituents, like benzol or others, were isolated and studied.

Under the brilliant leadership of Kékulé, a successful attempt was made to correlate the rapidly increasing new experimental observations in organic chemistry into a new theory which would try to explain all the numerous facts; a theory which became the sign-post to the roads of further achievements.

The discovery of quickly succeeding processes for making from coal-tar derivatives numerous artificial dyes, rivaling, if not surpassing, the most brilliant colors of nature, made the group of bold investigators still bolder. Research in organic chemistry began to find rapid rewards; entirely new and successful industries based on purely scientific data were springing up in England and France, as well as in Germany.

Some wide-awake leaders of these new enterprises, more particularly in Germany, soon learned that they were never hampered by too much knowledge, but that, on the contrary, they were almost continuously handicapped in their impatient onward march by insufficient knowledge, or by misleading conceptions, if not by incorrect published facts. This is precisely where the study of organic chemistry received its greatest stimulating influence and soon put Germany, in this branch of science, ahead of all other nations.

Money and effort had to be spent freely for further research. The best scholars in chemistry were called into action. Some men, who were preparing themselves to become professors, were induced to take a leading part as directors in one or another of the new chemical enterprises. Others, who refused to forsake their teachers' career, were retained as advisers or guides, and, in several instances, the honor of being the discoverers of new processes, or a new dye, was made more substantial by financial rewards. The modest German university professor, who heretofore had lived within a rather narrow academic sphere, went through a process of evolution, where the rapidly growing chemical industry made him realize his latent powers and greater importance, and broadened his influence way beyond the confines of his lecture-room. Even if he were altruistic enough to remain indifferent to fame or money, he felt stimulated

by the very thought that he was helping, in a direct manner, to build up the nation and the world through the immediate application of the principles of science.

In the beginning, science did all the giving and chemical industry got most of the rewards; but soon the rôles began to change until frequently they became completely inverted. The universities did not furnish knowledge fast enough to keep pace with the requirements of the rapidly developing new industries. Modern research laboratories were organized by some large chemical factories on a scale never conceived before, with a lavishness which made the best equipped university laboratory appear like a timid attempt. Germany, so long behind France and England, had become the recognized leader in organic manufacturing processes, and developed a new industrial chemistry based more on the thorough knowledge of organic chemistry than on engineering skill.

In this relation, it is worth while to point out that the early organic industrial chemistry, through which Germany was soon to become so important, at first counted its output not in tons, but in pounds — not in size nor in quantity, but in variety and quality.

Now let us see how Germany won her spurs in chemical engineering as well. At the beginning, the manufacturing problems in organic chemistry involved few, if any, serious engineering difficulties, but required, most of all, a sound theoretical knowledge of the subject; this put a premium on the scientist, and could afford, for a while at least, to ignore the engineer. But when growing developments began to claim the help of good engineers, there was no difficulty whatsoever in supplying them, nor in making them coöperate with the scientists. In fact, since then, Germany has solved, just as successfully, some of the most extraordinary chemical engineering problems ever undertaken, although the development of such processes was entered upon at first from the purely scientific side.

In almost every case, it was only after the underlying scientific facts had been well established, that any attempt was made to develop them commercially. Healthy commercial development of new scientific processes does not build its hope of success upon the coöperation of that class of " promoters " which are always eager to find any available pretext for making " quick money," and whose

scientific ignorance contributes conveniently to their comfort by not interfering too much with their self-assurance and their voluble assertions. The history of most of the successful recent chemical processes abounds in examples where, even after the underlying principles were well established, long and costly preparatory teamwork had to be undertaken; where foremost scientists, as well as engineers of great ability, had to combine their knowledge, their skill, their perseverance, with the support of large chemical companies, who, in their turn, could rely on the financial backing of strong banking concerns, well advised by tried expert specialists.

History does not record how many processes thus submitted to careful study were rejected because, on close examination, they were found to possess some hopeless shortcomings. In this way, numerous fruitless efforts and financial losses were averted, where less carefully accumulated knowledge might have induced less scrupulous promoters to secure money for plausible but ill-advised enterprises.

In the history of the manufacture of artificial dyes, no chapter gives a more striking instance of long, assiduous and expensive preliminary work of the highest order than the development of the industrial synthesis of indigo. Here was a substance of enormous consumption which, until then, had been obtained from the tropics as a natural product of agriculture. Professor von Baeyer and his pupils, by long and marvelously clever laboratory work, succeeded in unraveling the chemical constitution of this indigo dye, and finally indicated some possible methods of synthesis. Notwithstanding all this, it took the Badische Aniline & Soda Fabrik about 20 years of patient research, carried out by a group of eminent chemists and engineers, before a satisfactory method was devised by which the artificial product could compete in price and in quality with natural indigo.

Germany, with her well administered and easily enforcible patent laws, has added, through this very agency, a most vital inducement for pioneer work in chemical industries. Who otherwise would dare to take the risk of all the expenses connected wih this class of creative work? Moreover, who would be induced to publish the result of his discoveries far and wide throughout the whole world in that stead-

ily flowing stream of patent literature, which, much sooner than any text-books or periodicals, enables one worker to be benefited and to be inspired by the publication of the latest work of others?

The development of some problems of industrial chemistry has enlisted the brilliant collaboration of men of so many different nationalities that the final success could not, with any measure of justice, be ascribed exclusively to one single race or nation; this is best illustrated by the invention of the different methods for the fixation of nitrogen from the air. This extraordinary achievement, although scarcely a few years old, seems already an ordinary link in the chain of common, current events of our busy life; and yet, the facts connected with this recent conquest reveal a modern tale of great deeds of the race — an Epos of Applied Science. Its story began the day when chemistry taught us how indispensable are the nitrogeneous substances for the growth of all living beings.

Generally speaking, the most expensive food-stuffs are precisely those which contain most nitrogen; for the simple reason that there is, and always has been, at sometime or another, a shortage of nitrogeneous foods in the world. Agriculture furnishes us these proteid- or nitrogen-containing bodies, whether we eat them directly as vegetable products, or indirectly as animals which have assimilated the proteids from plants. It so happens, however, that by our ill-balanced methods of agriculture, we take nitrogen from the soil much faster than it is supplied to the soil through natural agencies. We have tried to remedy this discrepancy by enriching the soil with manure or other fertilizers, but this has been found totally insufficient, especially with our methods of intensive culture — our fields want more nitrogen. So agriculture has been looking anxiously around to find new sources of nitrogen fertilizer. For a short time, an excellent supply was found in the guano deposits of Peru; but this material was used up so eagerly that the supply lasted only a very few years. In the meantime, the ammonium salts recovered from the by-products of the gas-works have come into steady use as nitrogen fertilizer. But, here again, the supply is entirely insufficient, and during the later period our main reliance has been placed on the natural beds of sodium nitrate, which are found in the desert regions of Chile. This has been, of late, our principal source

of nitrogen for agriculture, as well as for the many industries which require saltpeter or nitric acid.

In 1898, Sir William Crookes, in his memorable presidential address before the British Association for the Advancement of Science, called our attention to the threatening fact that, at the increasing rate of consumption, the nitrate beds of Chile would be exhausted before the middle of this century. Here was a warning raised to the human race by one of the deepest scientific thinkers of our generation. It meant no more nor less than that before long our race would be confronted with nitrogen starvation. In a given country, all other conditions being equal, the abundance or the lack of nitrogen available for nutrition is a paramount factor in the degree of general welfare, or of physical decadence. The less nitrogen there is available as food-stuffs, the nearer the population is to starvation. The great famines in such nitrogen-deficient countries as India and China and Russia are sad examples of nitrogen starvation.

And yet, nitrogen, as such, is so abundant in nature that it constitutes four-fifths of the air we breathe. Every square mile of our atmosphere contains nitrogen enough to satisfy our total present consumption for over half a century. However, this nitrogen is unavailable so long as we do not find means to make it enter into some suitable chemical combination. Morever, nitrogen was generally considered inactive and inert, because it does not enter readily into chemical combination.

William Crookes' disquieting message of rapidly approaching nitrogen starvation did not cause much worry to politicians — they seldom look so far ahead into the future. But, to the men of science, it rang like a reproach to the human race. Here, then, we were in possession of an inexhaustible store of nitrogen in the air, and yet, unless we found some practical means for tying some of it into a suitable chemical combination, we would soon be in a position similar to that of a shipwrecked sailor, drifting around on an immense ocean of brine, and yet slowly dying for lack of drinking water.

As a guiding beacon, there was, however, that simple experiment, carried out in a little glass tube, as far back as 1785, by both Caven-

dish and Priestley, which showed that if electric sparks were passed through air, the oxygen thereof was able to burn some of the nitrogen and to engender nitrous vapors. This seemingly unimportant laboratory curiosity, so long dormant in the text-books, was made a starting point by Charles S. Bradley and D. R. Lovejoy, in Niagara Falls, for creating the first industrial apparatus for converting the nitrogen of the air into nitric acid by means of the electric arc. As early as 1902, they published their results as well as the details of their apparatus. Although they operated only one full-sized unit, they demonstrated conclusively that nitric acid could thus be produced from the air in unlimited quantities. We shall examine later the reasons why this pioneer enterprise proved a commercial insuccess; but to these two American inventors belongs, undoubtedly, the credit of having furnished the first answer to the distress call of Sir William Crookes.

In the meantime, many other investigators were at work at the same problem, and soon from Norway's abundant waterfalls came the news that Birkeland and Eyde had solved successfully, and on a commercial scale, the same problem by a differently constructed apparatus. The Germans, too, were working on the same subject, and we heard that Schoenherr, also Pauling, had evolved still other methods, all, however, based on the Cavendish-Priestley principle of oxidation of nitrogen. In Norway alone, the artificial saltpeter factories use now, day and night, over 200,000 electrical horse-power, which will soon be doubled; while a further addition is contemplated which will bring the volume of electric current consumed to about 500,000 horse-power. The capital invested at present in these works amounts to $27,000,000.

Frank and Caro, in Germany, succeeded in creating another profitable industrial process whereby nitrogen could be fixed by carbide of calcium, which converts it into calcium cyanamide, an excellent fertilizer by itself. By the action of steam on cyanamide, ammonia is produced, or it can be made the starting point of the manufacture of cyanides, so profusely used for the treatment of gold and silver ores.

Although the synthetic nitrates have found a field of their own, their utilization for fertilizers is smaller than that of the cyanamide; and the latter industry represents, to-day, an investment of about

$30,000,000, with three factories in Germany, two in Norway, two in Sweden, one in France, one in Switzerland, two in Italy, one in Austria, one in Japan, one in Canada, but not any in the United States. The total output of cyanamide is valued at $15,000,000 yearly and employs 200,000 horse-power, and preparations are made at almost every existing plant for further extensions. An English company is contemplating the application of 1,000,000 horse-power to the production of cyanamide and its derivatives, 600,000 of which have been secured in Norway and 400,000 in Iceland.

But still other processes are being developed, based on the fact that certain metals or metalloids can absorb nitrogen, and can thus be converted into nitrides; the latter can either be used directly as fertilizers or they can be made to produce ammonia under suitable treatment. The most important of these nitride processes seems to be that of Serpek, who, in his experimental factory at Niedermorschweiler, succeeded in obtaining aluminum nitride in almost theoretical quantities, with the use of an amount of electrical energy eight times less than that needed for the Birkeland-Eyde process and one-half less than for the cyanamide process, the results being calculated for equal weights of "fixed" nitrogen. A French company has taken up the commercial application of this process which can furnish, besides ammonia, pure alumina for the manufacture of aluminum metal.

An exceptionally ingenious process for the direct synthesis of ammonia, by the direct union of hydrogen with nitrogen, has been developed by Haber in conjunction with the chemists and engineers of the Badische Aniline & Soda Fabrik. The process has the advantage that it is not, like the other nitrogen-fixation processes, paramountly dependent upon cheap power; for this reason, if for no other, it seems to be destined to a more ready application. The fact that the group of the three German chemical companies which control the process have sold out their former holdings in the Norwegian enterprises to a Norwegian-French group, and are now devoting their energies to the commercial installation of the Haber process, has quite some significance as to expectations for the future.

The question naturally arises: Will there be an over-production and will these different rival processes not kill each other in slaughtering prices beyond remunerative production? As to over-produc-

tion, we should bear in mind that nitrogen fertilizers are already used at the rate of about $200,000,000 worth a year, and that any decrease in price, and, more particularly, better education in farming, will probably lead to an enormously increased consumption. It is worth mentioning here that, in 1825, the first ship-load of Chile saltpeter which was sent to Europe could find no buyer, and was finally thrown into the sea as useless material. Then again, processes for nitric acid and processes for ammonia, instead of interfering, are supplementary to each other, because the world needs ammonia and ammonium salts, as well as nitric acid or nitrates. It should be pointed out also, that, ultimately, the production of ammonium nitrate may prove the most desirable method so as to minimize freight; for this salt contains much more nitrogen to the ton than is the case with the more bulky calcium-salt under which form synthetic nitrates are now put into the market.

Before leaving this subject, let us examine why Bradley and Lovejoy's efforts came to a standstill where others succeeded. First of all, the cost of power at Niagara Falls is three to five times higher than in Norway, and although at the time this was not strictly prohibitive for the manufacture of nitric acid, it was entirely beyond hope for the production of fertilizers. The relatively high cost of power in our country is the reason why the cyanamide enterprise had to locate on the Canadian side of Niagara Falls, and why, up till now, outside of an experimental plant in the South (a 4000 horse-power installation in North Carolina, using the Pauling process), the whole United States has not a single synthetic nitrogen fertilizer works. The yields of the Bradley-Lovejoy apparatus were rather good. They succeeded in converting as much as 2½ percent. of the air, which is somewhat better than their successors are able to accomplish. But their units, 12 kilowatts, were very much smaller than the 1000 to 3000 kilowatts now used in Norway; they were also more delicate to handle, all of which made installation and operation considerably more expensive. However, this was the natural phase through which any pioneer industrial development has to go, and it is more than probable that in the natural order of events, these imperfections would have been eliminated.

But the killing stroke came when financial support was suddenly withdrawn. In the successful solution of similar industrial prob-

lems, the originators in Europe were not only backed by scientifically well-advised bankers, but they were helped to the rapid solution of all the side problems by a group of specially selected scientific collaborators, as well as by all the resourcefulness of well-established chemical enterprises. That such conditions are possible in the United States has been demonstrated by the splendid team-work which led to the development of the modern tungsten lamp in the research laboratories of the General Electric Company, and to the development of the Tesla polyphase motor by the group of engineers of the Westinghouse Company.

True, there are endless subjects of research and development which can be brought to success by the efforts of single independent inventors, but there are some problems of applied science which are so vast, so much surrounded with ramifying difficulties, that no one man, nor two men, however exceptional, can furnish either the brains or the money necessary for leading to success within a reasonable time. For such special problems, the rapid coöperation of numerous experts and the financial resources of large establishments are indispensable. All these examples of the struggle for efficiency and improvement demonstrate why, in industrial chemistry, the question of *dollars and cents* has to be taken very much into consideration.

From this standpoint at least, the "dollars and cents" argument can be interpreted as a symptom of industrial efficiency, and thus the definition sounds no longer as a reproach. With some allowable degree of accuracy, it formulates one of the economic aspects of any acceptable industrial chemical process. Indeed, barring special conditions, as, for instance, incompetent or reckless management, unfair competition, monopolies, or other artificial privileges, the money success of a chemical process is the cash plebiscite of approval of the consumers. It is bound, after a time at least, to weed out the inefficient methods.

Some chemists, who have little or no experience with industrial enterprises, are too much over-inclined to judge a chemical process exclusively from the standpoint of the chemical reactions involved therein, without sufficient regard to engineering difficulties, financial requirements, labor problems, market and trade conditions, rapid development of the art involving frequent disturbing improvements in methods and expensive changes in equipment, advantages or dis-

advantages of the location of the plant, and other conditions so numerous and variable that many of them can hardly be foreseen even by men of experience. And yet, these seemingly secondary considerations most of the time become the deciding factor of success or failure of an otherwise well-conceived chemical process.

The cost of transportation alone will frequently decide whether a certain chemical process is economically possible or not. For instance, the big Washoe smelter, in Montana, wastes enough sulphurdioxide-gas to make daily 1800 tons of sulphuric acid, but that smelter is too far distant from any possible market for such a quantity of otherwise valuable material.

Another example of the kind is found in the natural deposits of soda, or soda lakes, in California. One of these soda lakes contains from thirty to forty-two million tons of soda. Here is a natural source of supply which would be ample to satisfy the world's demand for many years to come. Similar deposits exist in other parts of the world, but the cost of transportation to a sufficiently large and profitable market is so exorbitant that, in the meantime, it is cheaper to erect at more convenient points expensive chemical works in which soda is made chemically and from where the market can be supplied more profitably.

In addition, we can cite the artificial nitrate processes in Norway, which, notwithstanding their low efficiency and expensive installation, can furnish nitrate in competition with the natural nitrate beds of Chile, because the latter are hampered by the cost of extraction from the soil where fuel for crystallization is expensive, in addition to the considerable cost of freight.

There is no better example, illustrating the far-reaching effect of seemingly secondary conditions upon the success of a chemical process, than the history of the Leblanc soda process. This famous process was the forerunner of chemical industry: for almost a century, it dominated the enormous group of industries of heavy chemicals, so expressively called by the French: "La Grande Industrie Chimique," and now we are witnesses of the lingering death agonies of this chemical colossus. Through the Leblanc process. large fortunes have been made and lost; but even after its death, it will leave a treasure of information to science and chemical engineering, the value of which can hardly be overestimated. Here,

then, is a very well worked-out process, admirably studied in all its details, which, in its heroic struggle for existence, has drawn upon every conceivable resource of ingenuity furnished by the most learned chemists and the most skilful engineers, who succeeded in bringing it to an extraordinary degree of perfection, and which, nevertheless, has to succumb before inexorable, although seemingly secondary, conditions.

Strange to say, its competitor, the Solvay process, entered into the arena after a succession of failures. When Solvay, as a young man, took up this process, he was, himself, totally ignorant of the fact that no less than about a dozen able chemists had invented and reinvented the very reaction on which he had pinned his faith; that, furthermore, some had tried it on a commercial scale, and had, in every instance, encountered failure. At that time, all this must, undoubtedly, have been to young Solvay a revelation sufficient to dishearten almost anybody. But he had one predominant thought to which he clung as a last hope of success, and which would probably have escaped most chemists; he reasoned that, in this process, he starts from two watery solutions, which, when brought together, precipitate a dry product, bicarbonate of soda; in the Leblanc process, the raw materials must be melted together, with the use of expensive fuel, after which the mass is dissolved in water, losing all these valuable heat units, while more heat has again to be applied to evaporate to dryness.

After all, most of the weakness of the Leblanc process resides in the greater consumption of fuel. But the cost of fuel, here again, is determined by freight rates. This is so true that we find that the last few Leblanc works which manage to keep alive are exactly those which are situated near unusually favorable shipping points, where they can obtain cheap fuel, as well as cheap raw materials, and whence they can most advantageously reach certain profitable markets.

But another tremendous handicap of the Leblanc process is that it gives as one of its by-products hydrochloric acid. Profitable use for this acid, as such, can be found only to a limited extent. It is true that hydrochloric acid could be used in much larger quantities for many purposes where sulphuric acid is used now, but it has, against sulphuric acid, a great freight disadvantage. In its com-

mercially available condition, it is an aqueous solution, containing only about one-third of real acid, so that the transportation of one ton of acid practically involves the extra cost of freight of about two tons of water. Furthermore, the transportation of hydrochloric acid in anything but glass carboys involves very difficult problems in itself, so that the market for hydrochloric acid remains always within a relatively small zone from its point of production. However, for a while at least, an outlet for this hydrochloric acid was found by converting it into a dry material which can easily be transported; namely, chloride of lime or bleaching-powder.

The amount of bleaching-powder consumed in the world practically dictated the limited extent to which the Leblanc process could be profitably worked in competition with the Solvay process. But even this outlet has been blocked during these later years by the advent of the electrolytic alkali processes, which have sprung up successfully in several countries, and which give as a cheap by-product, chlorine, which is directly converted into chloride of lime. Today, any process which involves the production of large quantities of hydrochloric acid, beyond what the market can absorb as such, or as derivatives thereof, becomes a positive detriment, and foretells failure of the process. Even if we could afford to lose all the acid, the disposal of large quantities thereof conflicts immediately with laws and ordinances relative to the pollution of the atmosphere or streams, or the rights of neighbors, and occasions expensive damage suits.

Whatever is said about hydrochloric acid applies to some extent to chlorine, produced in the electrolytic manufacture of caustic soda. Here again, the development of the latter industry is limited, primarily, by the amount of chlorine, as such, or as chlorinated products, which the market can absorb. At any rate, chlorine can be produced so much cheaper by electrolytic caustic alkali processes than formerly, and in the meantime the market price of chloride of lime has already been cut about in half.

Inasmuch as the rather young electrolytic alkali industry has reached a considerable development in the United States, let us examine it somewhat closer. At present, the world's production of chloride of lime approximates about half a million tons. We used to import all our chloride of lime from Europe, until about fifteen

years ago, when the first successful electrolytic alkali works were started at Niagara Falls. That ingenious mercury cell of Hamilton Y. Castner — a pupil of Professor Chandler and one of the illustrious sons of the Columbia School of Mines — was first used, and his process still furnishes a large part of all the electrolytic caustic soda and chlorine manufactured here and abroad. At present, about 30,000 electrical horse-power are employed uninterruptedly for the different processes used in the United States, and our home production has increased to the point where, instead of importing chloride of lime, we shall soon be compelled to export our surplus production.

It looks now as if, for the moment at least, any sudden considerable increase in the production of chloride of lime would lead to overproduction until new channels of consumption of chloride of lime or other chlorine products can be found. However, new uses for chlorine are being found every day. The very fact that commercial hydrochloric acid of exceptional purity is now being manufactured in Niagara Falls by starting from chlorine, indicates clearly that conditions are being reversed; no longer than a few years ago, when chlorine was manufactured exclusively by means of hydrochloric acid, this would have sounded like a paradox.

The consumption of chlorine for the preparation of organic chlorination products utilized in the dye-stuff industry, is also increasing continually, and its use for the manufacture of tetra-chloride of carbon and so-called acetylen chlorination products, has reached quite some importance.

There is probably a much overlooked but wider opening for chlorinated solvents in the fact that ethylen-gas can be prepared now at considerably lower cost than acetylen, and that ethylen-chloride, or the old known "Dutch Liquid," is an unusually good solvent. It has, furthermore, the great advantage that its specific gravity is not too high, and its boiling point, too, is about the right temperature. It ought to be possible to make it at such a low price that it would find endless applications where the use of other chlorination solvents has thus far been impossible. The chlorination of ores for certain metallurgical processes may eventually open a still larger field of consumption for chlorine.

In the meantime, liquified chlorine gas, obtained by great com-

pression, or by intense refrigeration, has become an important article of commerce, which can be transported in strong steel cylinders. Its main utilization resides in the manufacture of tin chloride by the Goldschmidt process for reclaiming tin-scrap. It is finding, also, increased applications as a bleaching agent and for the purification of drinking water, as well as for the manufacture of various chlorination products. Its great handicap for rapid introduction is again the question of freight, where heavy and expensive containers become indispensable.

In most cases, the transportation problem of chlorine is solved more economically by handling it as chloride of lime, which, after all, represents chlorine or oxygen in solid form, easily transportable. It would seem as if the freight difficulty could easily be eliminated by producing the chlorine right at the spot of consumption. But this is not always so simple as it may appear. To begin with, the cost of an efficient plant for any electrolytic operation is always unusually high as compared to other chemical equipments. Then, also, small electrolytic alkali plants are not profitable to operate. Furthermore, the conditions for producing cheap chlorine depend on many different factors, which all have to coördinate advantageously; for instance, cheap power, cheap fuel, and cheap raw materials are essential, while, at the same time, a profitable outlet must be found for the caustic soda.

Lately, there has been a considerable reduction of the market price of caustic soda; all this may have for effect that the less efficient electrolytic processes will gradually be eliminated; although this may not necessarily be the case for smaller plants which do not compete in the open market, but consume their own output for some special purpose.

Several distinct types of electrolytic cells are now in successful use, but experience seems to demonstrate that the so-called diaphragm cells are cheapest to construct and to operate, provided, however, no exception be taken to the fact that the caustic soda obtained from diaphragm cells always contains some sodium chloride, usually varying from 2 to 3 percent., which it is not practical to eliminate, but which, for almost all purposes, does not interfere in the least with its commercial use. Mercury cells give a much purer caustic soda, and this may, in some cases, compensate for their more

expensive equipment and operation. Moreover, there are some purposes where the initial caustic solution of rather high concentration, produced directly in these cells, can be used as it is without further treatment, thus obviating further concentration and cost of fuel.

The expenses for evaporation and elimination of salt from the raw caustic solutions increase to an exaggerated extent with some types of diaphragm cells, which produce only very weak caustic liquors. This is also the case with the so-called "gravity cell," sometimes called the "bell type," or "Aussig type," of cell. But these gravity cells have the merit of dispensing with the delicate and expensive problems of diaphragms. On the other hand, their units are very small, and, on this account, they necessitate a rather complicated installation, occupying an unusually large floor space and expensive buildings. The general tendency is now towards cells which can be used in very large units, which can be housed economically, and of which the general cost of maintenance and renewal is small; some of the modern types of diaphragm cells are now successfully operating with 3000 to 5000 amperes per cell.

As to the possible future improvements in electrolytic alkali cells, we should mention that in some types the current efficiencies have practically reached their maximum, and average ampere efficiencies as high as 95 to 97 percent. have been obtained in continuous practice. The main difficulty is to reinforce these favorable results by the use of lower voltage, without making the units unnecessarily bulky, or expensive in construction, or in maintenance, all factors which soon outweigh any intended saving of electric current. Here, more than in any other branch of chemical engineering, it is easy enough to determine how "good" a cell is on a limited trial, but it takes expensive, long continuous use on a full commercial scale, running uninterruptedly day and night for years, to find out how "bad" it is for real commercial practice.

In relation to the electrolytic alkali industry, a great mistake is frequently committed by considering the question of power as paramount; true enough, cheap power is very important, almost essential, but certainly it is not everything. There have been cases where it was found much cheaper in the end to pay almost double for electric current in a certain locality, than in another site not far distant from the first, for the simple reason that the cheaper power

supply was hampered by frequent interruptions and expensive disturbances, which more than offset any possible saving in cost of power. In further corroboration, it is well known that some of the most successful electrolytic soda manufacturers have found it to their advantage to sacrifice power by running their cells at decidedly higher voltage than is strictly necessary — which simply means consuming more power — and this in order to be able to use higher current densities, thereby increasing considerably the output of the same size units, and thus economizing on the general cost of plant operation. Here is one of the ever recurring instances in chemical manufacturing where it becomes more advantageous to sacrifice apparent theoretical efficiency in favor of industrial expediency.

All this does not diminish the fact that the larger electro-chemical industries can thrive only where cheap power is available. Modern progress of electrical engineering has given us the means to utilize so-called natural powers; until now, however, we have only availed ourselves of the water-power developed from rivers, lakes, and waterfalls. As far as larger electric power generation is concerned, the use of the wind, or the tide, or the heat of the sun, represents, up till now, nothing much beyond a mere hope of future possibilities.

In the meantime, it so happens, unfortunately, that many of the most abundant water-powers of the world are situated in places of difficult access, far removed from the zone of possible utilization. But, precisely on this account, it would appear, at first sight, as if the United States, with some of her big water-powers situated nearer to active centers of consumption, would be in an exceptionally favorable condition for the development of electrochemical industries. On closer examination, we find, however, that the cost of water-power, as sold to manufacturers, is, in general, much higher than might be expected; at any rate, it is considerably more expensive than the cost of electric power utilized in the Norway nitrate enterprises.

This is principally due to the fact that in the United States, water-power, before it is utilized by the electrolytic manufacturer, has already to pay one, two, and sometimes three, profits, to as many intermediate interests, which act as so many middlemen between the original water-power and the consumer. Only in such

instances as in Norway, where the electrochemical enterprise and the development of the water-power are practically in the same hands, can electric current be calculated at its real cheapest cost. Neither should the fact be overlooked that the best of our water-powers in the East are situated rather far inland. Although this does not matter much for the home market, it puts us at a decided disadvantage for the exportation of manufactured goods, in comparison again with Norway, where the electrolytic plants are situated quite close to a good sea-harbor open in all seasons.

Some electrochemical enterprises require cheap fuel just as much as cheap power; and, on this account, it has proved sometimes more advantageous to dispense entirely with water-power by generating gas for fuel as well as for power from cheap coal or still cheaper peat. At present, most of our ways of using coal are still cumbersome and wasteful, although several efficient methods have been developed which some day will probably be used almost exclusively, principally in such places where lower grades of cheap coal are obtainable.

I refer here particularly to the valuable pioneer work of that great industrial chemist, Mond, on cheap water-gas production, by the use of a limited amount of air in conjunction with water vapor. More recently, this process has been extended by Caro, Frank and others, to the direct conversion of undried peat into fuel-gas. By the use of these processes, peat or lower grades of coal, totally unsuitable for other purposes, containing, in some instances, as much as 60 to 70 percent. of incombustible constituents, can be used to good advantage in the production of fuel for power generation. Whether Mond-gas will ever be found advantageous for distribution to long distances is questionable, because its heating value per cubic foot is rather less than that of ordinary water-gas, but this does not interfere with its efficient use in internal combustion engines.

In general, our methods for producing or utilizing gas in our cities do scant justice to the extended opportunities indicated by our newer knowledge. Good fuel-gas could be manufactured and distributed to the individual household consumer at considerably cheaper rates, if it were not for antiquated municipal specifications, which keep on prescribing photometric tests instead of in-

sisting on standards of fuel value, which makes the cost of production unnecessarily high, and disregards the fact that, for lighting, the Welsbach mantle has rendered obsolete the use of highly carbureted gas as a bare flame. But for those unfortunate specifications, cheap fuel-gas might be produced at some advantageous central point, where very cheap coal is available; such heating gas could be distributed to every house and every factory, where it could be used cleanly and advantageously, like natural gas, doing away at once with the black coal smoke nuisance, which now practically compels a city like New York to use nothing but the more expensive grades of anthracite coal. It would eliminate, at the same time, all the bother and expense caused through the clumsy and expensive methods of transportation and handling of coal and ashes; it would relieve us from many unnecessary middlemen which now exist between coal and its final consumer.

The newer large-sized internal combustion engines are introducing increasing opportunities for new centers of power production where waste gas of blast-furnaces or coke-ovens, or where deposits of inferior coal or peat, are available. If such centers are situated near tidewater, this may render them still more advantageous for some electrochemical industries, which, until now, were compelled to locate near some inland water-powers. Nor should we overlook the fact that the newer methods for the production of cheap fuel-gas offer excellent opportunities for an increased production of valuable tar by-products, and more particularly of ammonium salts; the latter would help to a not inconsiderable extent in furnishing more nitrogen fertilizer.

It is somewhat remarkable that a greater effort has already been made to start the industrial synthesis of nitrogen products than to economize all these hitherto wasted sources of ammonia. In fact, science indicates still other ways, somewhat of a more radical nature, for correcting the nitrogen deficiencies in relation to our food supply. Indeed, if we will look at this matter from a much broader standpoint, we may find that, after all, the shortage of nitrogen in the world is attributable, to a large extent, to our rather one-sided system of agriculture. We do not sufficiently take advantage of the fact that certain plants, for instance those of the group of Leguminosæ, have the valuable property of easily assimilating nitro-

gen from the air, without the necessity of nitrogen fertilizers. In this way, the culture of certain Leguminosæ can insure enough nitrogen for the soil, so that, in rotation with nitrogen consuming crops, like wheat, we could dispense with the necessity of supplying any artificial nitrogen fertilizers. The present nitrogen deficiency is influenced further by two other causes: The first cause is our unnecessarily exaggerated meat diet, in which we try to find our proteid requirements, and which compels us to raise so many cattle, while the amount of land which feeds one head of cattle, could furnish, if properly cultivated, abundant vegetable food for a family of five. The second cause is our insufficient knowledge of the way to grow and prepare for human food just those vegetables which are richest in proteids. Unfortunately, it so happens that exactly such plants as, for instance, the soy-bean are not by any means easily rendered palatable and digestible; while any savage can eat raw meat, or can readily cook, boil or roast it for consumption.

On this subject, we can learn much from some Eastern people, like the Japanese, who have become experts in the art of preparing a variety of agreeable food products from that refractory soy-bean, which contains such an astonishingly large amount of nutritious proteids, and which, long ago, became for Japan a wholesome, staple article of diet. But, on this subject, the Western races have not yet progressed much beyond the point of preparing cattle-feed and paint oil from the soy-bean, although the more extended culture of this, or similar plants, might work about a revolution in our agricultural economics.

Agriculture, after all, is nothing but a very important branch of industrial chemistry, although most people seem to ignore the fact that the whole prosperity of agriculture is based on the success of that photochemical reaction which, under the influence of the light of the sun, causes the carbon dioxide of the air to be assimilated by the chlorophyl of the plant.

It is not impossible that photochemistry, which hitherto has busied itself, almost exclusively, within the narrow limits of the art of making photographic images, will, some day, attain a development of usefulness at least as important as all other branches of physical chemistry. In this broader sense, photochemistry seems

an inviting subject for the agricultural chemist. The possible rewards in store in this almost virgin field may, in their turn, by that effect of superinduction between industry and science, bring about a rapid development similar to what we have witnessed in the advancement of electricity, as well as chemistry, which both began to progress by bounds and leaps, way ahead of other sciences, as soon as their growing industrial applications put a high premium on further research.

Photochemistry may allow us some day to obtain chemical effects hitherto undreamed of. In general, the action of light in chemical reactions seems incomparably less brutal than all means used heretofore in chemistry. This is the probable secret of the subtle chemical syntheses which happen in plant life. To try to duplicate these delicate reactions of nature by our present methods of high temperatures, electrolysis, strong chemicals and other similar torture-processes, seems like trying to imitate a masterpiece of Gounod by exploding a dynamite cartridge between the strings of a piano.

But there are endless other directions for scientific research, relating to industrial applications, which, until now, do not seem to have received sufficient attention. For instance, from a chemical standpoint, the richest chemical enterprise of the United States, the petroleum industry, has hitherto chiefly busied itself with a rather primitive treatment of this valuable raw material, and little or no attention has been paid to any methods for transforming at least a part of these hydrocarbons into more ennobled products of commerce than mere fuel or illuminants. A hint as to the enormous possibilities which may be in store in that direction, is suggested by the recent work in Germany and England on synthetic rubber; the only factor which prevents extending the laboratory synthesis of rubber into an immense industrial undertaking is that we have not yet learned how to make cheaply the isoprene or other similar non-saturated hydrocarbons which are the starting point in the process which changes their molecules, by polymerization, into rubber.

Nor has our science begun to find the best uses for such inexpensive and never exhaustible vegetable products as cellulose or starch. Quite true, several important manufactures, like that of paper, nitrocellulose, glucose, alcohol, vinegar and some others, have been

built on it; but to the chemist at least, it seems as if a much greater development is possible in the cheaper and more extended production of artificial fiber. Although we have succeeded in making so-called artificial silk, this article is still very expensive; furthermore, we have not yet produced a cheap, good, artificial fiber of the quality of wool.

If we have made ourselves independent of Chile for our nitrogen supply, we are still absolutely at the mercy of the Stassfurt mines in Germany for our requirements of soluble potash-salts, which are just as necessary for agriculture. Shall we succeed in utilizing some of the proposed methods for converting that abundant supply of feldspar, or other insoluble potash-bearing rocks, into soluble potash-salts by combining the expensive heat treatment with the production of another material like cement, which would render the cost of fuel less exorbitant? Or shall the problem be solved in setting free soluble potassium salts as a by-product in a reaction engendering other staple products consumed in large quantities?

We have several astonishingly conflicting theories about the constitution of the center of the globe, but we have not yet developed the means to penetrate the world's crust beyond some deep mines — merely an imperceptible faint scratch on the surface — and in the meantime, we keep on guessing, while to-day astronomers know already more about the surface of the planet Mars than we know about the interior of the globe on which we live. Nor have we learned to develop or utilize the tremendous pressures under which most minerals have been formed, and still less do we possess the means to try these pressures, in conjunction with intensely high temperatures.

No end of work is in store for the research chemist, as well as for the chemical engineer, who can think by himself, without always following the beaten track. We are only at the beginning of our successes, and yet, when we stop to look back to see what has been accomplished during the last generations, that big jump from the rule-of-thumb to applied science is nothing short of marvelous. Whoever is acquainted with the condition of human thought to-day must find it strange, after all, that scarcely seventy years ago, Mayer met with derision even amongst the scientists of the time,

when he announced to the world that simple but fundamental principle of the conservation of energy.

We can hardly conceive that just about the time the Columbia School of Mines was founded, Liebig was still ridiculing Pasteur's ideas on the intervention of micro-organisms in fermentation, which have proved so fecund in the most epoch-making applications in science, medicine, surgery and sanitation, as well as in many industries. Fortunately, true science, contrary to other human avocations, recognizes nobody as an "authority," and is willing to change her beliefs as often as better studied facts warrant it; this difference has been the most vital cause of her never ceasing progress. To the younger generation, surrounded with research laboratories everywhere, it may cause astonishment to learn that scarcely fifty years ago, that great benefactor of humanity, Pasteur, was still repeating his pathetic pleadings with the French government to give him more suitable quarters than a damp, poorly lighted basement, in which he was compelled to carry on his research; and this was, then, the condition of affairs of no less a place than Paris, the same Paris that was spending, just at that time, endless millions for the building of her new Opera-Palace. Such facts should not be overlooked by those who might think that America has been too slow in fostering chemical research.

If the United States has not participated as early as some European countries in the development of industrial chemistry, this was chiefly because conditions here were so totally different from those of nations like Germany, England and France, that they did not warrant any such premature efforts. In a country as full of primary resources, agriculture, forests, mines, and the more elementary industries directly connected therewith, as well as the problems of transportation, appealed more urgently to American intellectual men of enterprise. Why should anybody here have tried to introduce new difficult or risky chemical industries, when on every side more urgently important fields of enterprise were inviting all men of initiative?

Chemical industries develop along the lines furnished by the most immediate needs of a country. Our sulphuric acid industry, which can boast to-day of a yearly production of about three million tons,

had to begin in an exceedingly humble way, and the first small amounts of sulphuric acid manufactured here found a very scant outlet. It required the growth of such fields of application as petroleum refining, superphosphates, explosives and others, before the sulphuric acid industry could grow to what it is to-day.

At present, similar influences are still dominating our chemical industries; they are generally directed to the mass production of partly manufactured articles. This allows us to export, at present, to Germany, chemicals in crude form, but in greater value than the total sum of all the chemical products we are importing from her; although it can not be denied that a considerable part of our imports are products like alizarine, indigo, aniline dyes and similar synthetic products which require higher chemical manufacturing skill. In this connection, it may be pointed out that our exports of oleomargarine, to Germany alone, are about equivalent to our imports of aniline dyes.

But all this does not alter the fact that in several important chemical industries the United States has been a pioneer. Such flourishing enterprises as that of the artificial abrasives, carborundum and alundum, calcium carbide, aluminum and many others, testify how soon we have learned to avail ourselves of some of our water-power.

One of the most important chemical industries of the world, the sulphite cellulose industry, of which the total annual production amounts to three and a half million tons, was originated and developed by a chemist in Philadelphia, B. C. Tilgman. But its further development was stopped for awhile on account of the same old trouble, lack of funds, after $40,000 were spent, until some years later, it was taken up again in Europe and reintroduced in the United States, where it has developed to an annual production of over a million tons. What has been accomplished in America in chemical enterprises, and what is going on now in industrial research, has been brilliantly set forth by Mr. Arthur D. Little.[1] Nor at any time in the history of the United States was chemistry neglected in this country; this has recently been brought to light in

[1] *Journal of Industrial and Engineering Chemistry*, Vol. 5, No. 10, October, 1913.

the most convincing manner by Professor Edgar F. Smith of Philadelphia.[2] The altruistic fervor of that little group of earlier American chemists, who, in 1792, founded the Chemical Society of Philadelphia (probably the very first chemical society in the world), and in 1811, the Columbia Chemical Society of Philadelphia, is best illustrated by an extract of one of the addresses read at their meeting in 1798:

> The only true basis on which the independence of our country can rest are agriculture and manufactures. To the promotion of these nothing tends in a higher degree than chemistry. It is this science which teaches man how to correct the bad qualities of the land he cultivates by a proper application of the various species of manure, and it is by means of a knowledge of this science that he is enabled to pursue the metals through the various forms they put on in the earth, separate them from substances which render them useless, and at length manufacture them into the various forms for use and ornament in which we see them. If such are the effects of chemistry, how much should the wish for its promotion be excited in the breast of every American! It is to a general diffusion of knowledge of this science, next to the virtue of our countrymen, that we are to look for the firm establishment of our independence. And may your endeavors, gentlemen, in this cause, entitle you to the gratitude of your fellow-citizens.

This early scientific spirit has been kept alive throughout the following century by such American chemists as Robert Hare, E. N. Horsford, Wolcott Gibbs, Sterry Hunt, Lawrence Smith, Carey Lea, Josiah P. Cooke, John W. Draper, Willard Gibbs and many others still living.

Present conditions in America can be measured by the fact that the American Chemical Society alone has over 7000 members, and the Chemists' Club of New York has more than a thousand members, without counting the more specialized chemical organizations, equally active, like the American Institute of Chemical Engineers, the American Electrochemical Society and many others.

During the later years, chemical research is going on with increasing vigor, more specially in relation to chemical problems presented by enterprises which at first sight seem rather remote from the so-called chemical industry. But the most striking symptom of newer times is that some wealthy men of America are rivaling each other in the endowment of scientific research on a scale never

[2] "Chemistry in America." Published by D. Appleton & Co. New York and London, 1914.

undertaken before, and that the scientific departments of our Government are enlarging their scope of usefulness at a rapid rate. But we are merely at the threshold of that new era where we shall learn better to use exact knowledge and efficiency to bring greater happiness and broader opportunities to all.

However imposing may appear the institutions founded by the Nobels, the Solvays, the Monds, the Carnegies, the Rockefellers and others, each of them is only a puny effort to what is bound to come when governments will do their full share. Fancy that if, for instance, the Rockefeller Institute is spending to good advantage about half a million dollars per annum for medical research, the chewing-gum bill of the United States alone would easily support half a dozen Rockefeller Institutes; and what a mere insignificant little trickle all these research funds amount to, if we have the courage to compare them to that powerful gushing stream of money which yearly drains the war budget of all nations.

In the meantime, the man of science is patient and continues his work steadily, if somewhat slowly, with the means hitherto at his disposal. His patience is inspired by the thought that he is not working for to-day, but for to-morrow. He is well aware that he is still surrounded by too many "men of yesterday," who delay the results of his work. Sometimes, however, he may feel discouraged that the very efficiency he has succeeded in reaching at the cost of so many painstaking efforts, in the economical production of such an article of endlessly possible uses, as Portland cement, is hopelessly lost many times over and over again, by the inefficiency, waste and graft of middlemen and political contractors, by the time it gets on our public roads, or in our public buildings. Sometimes the chaos of ignorant brutal waste which surrounds him everywhere may try his patience. Then again, he has a vision that he is planting a tree which will blossom for his children and will bear fruit for his grandchildren.

In the meantime, industrial chemistry, like all other applications of science, has gradually called into the world an increasing number of men of newer tendencies, men who bear in mind the future rather than the past, who have acquired the habit of thinking by well-established facts, instead of by words, of aiming at efficiency instead of striking haphazard at ill-defined purposes. Our various

engineering schools, our universities, are turning them out in ever increasing numbers, and better and better prepared for their work. Their very training has fitted them out to become the most broad-minded progressive citizens. However, their sphere of action, until now, seldom goes beyond that of private technical enterprises for private gain. And yet, there is not a chemist, not an engineer, worthy of the name, who would not prefer efficient, honorable public service, freed from party politics, to a mere money-making job. But most governments of the world have been run for so long almost exclusively by lawyer-politicians, that we have come to consider this as an unavoidable evil, until sometimes a large experiment of government by engineers, like the Panama Canal, opens our eyes to the fact that, after all, successful government is — first and last — a matter of efficiency, according to the principles of applied science.

Was it not one of our very earliest American chemists, Benjamin Thompson, of Massachusetts, later knighted in Europe as Count Rumford, who put in shape the rather entangled administration of Bavaria by introducing scientific methods of government? Pasteur was right when one day, exasperated by the politicians who were running his beloved France to ruin, he exclaimed: "In our century, science is the soul of the prosperity of nations and the living source of all progress. Undoubtedly, the tiring daily discussions of politics seem to be our guide. Empty appearances! — What really leads us forward are a few scientific discoveries and their applications."

PRESIDENT BUTLER.— Dr. Baekeland, Professor Chandler told us a few moments ago that attached to the delivery of the Chandler lecture was a punishment. It remains for me "to make the punishment fit the crime." A fund has been established in the University by friends and admirers of Professor Chandler, and their name is legion, to maintain the Chandler medal. This beautiful gold medal, made at the hands of the most expert of modern medallists, is intended to be given at the instance of the University to that eminent person who shall be selected from time to time to deliver the Chandler lecture. As a suitable punishment for the brilliant survey of industrial chemistry, its achievements and its

problems, which you have just delivered, I have the honor to present to you a copy of this beautiful gold medal, and it pleases me infinitely to present it in the presence of him with whose face and name you will always connect it. (Applause.)

PRESENTATION OF TABLET.

BY THE SOCIETY OF THE OLDER GRADUATES.

P. DE P. RICKETTS.— Mr. President and Gentlemen of the Board of Trustees of Columbia University:

The members of the Society of Older Graduates of Columbia, many of whom were students in the school whose fiftieth anniversary we celebrate today, feel that it is appropriate and fitting that they should on this occasion place on record their loyalty to their Alma Mater and their affection and respect for the men who taught them.

The School of Mines, organized on lines suggested by Professor

Thomas Egleston, has under the fostering care of old Columbia grown into a great institution, which has sent its graduates into all parts of the world and these graduates, because of the instruction received within its walls, have made the name of the Columbia School of Mines known in all civilized countries. May that name endure to add to the renown of Columbia in future years.

Properly to co-operate with the general committee having charge of this celebration and fully represent the Society of Older Graduates at the same, a committee of five was appointed by the Society with full power to take such action as might be deemed expedient

to commemorate the founding of the School of Mines and to express the abiding interest of the older graduates in their Alma

DOORWAY OF PRESENT SCHOOL OF MINES.

Mater. This committee decided upon the erection of a bronze tablet commemorating the founding of the School, and of its early faculty, the tablet to be placed at the entrance of the main building of the School of Mines, where it is the hope of the committee that

it may remain to be read in the years to come by the present and future graduates of the School, and be a permanent testimonial to the men who did so much to make the School of Mines what it is today.

On behalf of the Society of Older Graduates and its committee, I have the great honor and pleasure of presenting this commemorative tablet to Columbia University.

(Three cheers for de Peyster Ricketts! were called for and given.)

PRESIDENT BUTLER.— Professor Ricketts and Members of the Society of Older Graduates:

I accept with very great pleasure this admirable commemorative tablet of the first faculty of the School of Mines. It was a tender and charming thought on your part to put here, on this occasion, the names of the body of men to whom the School of Mines owes its early traditions and its early intellectual and scientific triumphs. It is not without interest that their names stand where Prof. Egleston's face must always see them. (The tablet is in the wall opposite the bronze bust of Egleston.— ED.) Of these illustrious men only three remained to come to this new site; and of the little band of three, two are fortunately left to us, in good health and spirits. They have told us of the personality and achievements of their associates' names on the tablet, and the story is interesting and inspiring. You may be sure that what they did in the School of Mines is remembered in our hearts, and that this tablet will similarly recall in a beautiful fashion from day to day some of the noblest personalities and finest scholars that ever lived. (Applause.)

THE BANQUET.

PROFESSOR JAMES F. KEMP, PRESIDING.

The last function of the Celebration was entrusted to a dinner committee composed of those veteran arrangers of Columbia banquets, the Executive Committee of the Early Eighties. Renault for the gustatory, Mulford for the decorative, and Reed for the musical, with Sawyer as chairman, produced a dinner memorable in numbers, perfection of detail, and spirit.

After the usual preliminary emollients 550 men took their places at numerous small tables, arranged with Romaine's accustomed care to combine congenial groups. Above the speakers' table blazed a large electric sign —" 1864 School of Mines 1914." Columbia banners covered the walls, and the Mines emblems, pick, hammer, and shovel, the real things, but fastened with stout wire to prevent accidents, formed rosettes on the columns.

Blue and gold menus and leaflets of specially selected songs announced the attractions of the evening. Unannounced, but not less important to the occasion, was the time limit successfully impressed upon the speakers, resulting in a series of short, snappy talks.

During the dinner the student band provided the music, a Glee Club quartette set the pace for the singing, and Charley Reed on a chair amply sustained his repute as leader.

During the progress of the dinner, the following wireless messages were received by a sputtering instrument high up in the hall, and were read by the Chairman:

From the Gates of Paradise — On calling the roll, I find a few of the faculty to be "in Heaven above where all is love." Great injustice has been done these excellent men.— ST. PETER.

To NICHOLAS MURRAY BUTLER — Well done, good and faithful servant. You have built a great superstructure upon my University foundation.— F. A. P. BARNARD.

To the Older Graduates and the Early and Upper Eighties — It is true that my furnace was zero meters high; that is to say, it was a hole in the ground. This was not necessary but could not however be avoided.— TUBAL CAIN.

From SIR CHARLES LYELL — In company with Professor Newberry, have investigated the shining shore and report that it is ripple-marked, sun-cracked, and bored by annelids and beach-loving brachipods. Back from the shore grow ferns, conifers, and equisetæ.

From SIR ISAAC NEWTON — In collaboration with Professor Rood. experiments with diffraction gratings established bright scarlet as essential cravat color.

To DOCTOR CHANDLER — No trouble with the milk in Hades. No H_2S in the air.— LAVOISIER.

PRESIDENT FREDERICK A. P. BARNARD.

JAMES F. KEMP.— Men of Columbia and friends: Before we pass to that part of the program which is cast in a lighter vein, we have a welcome duty and yet a great privilege to perform. We must remember the founders of the School of Mines, those far-sighted men who fifty years ago started the institution which has brought us together this evening. I have selected eight of our Alumni to give their names, and then we will all rise and drink a silent toast in their memory.

ARTHUR L. WALKER.— I name you, sir, Thomas Egleston, the originator of the School of Mines, to whose zeal, ability, faith, and perseverance we owe this admirable institution.

AMBROSE D. HENRY.— Next to the name of Egleston, I will place the name of President Frederick A. P. Barnard whose confidence as a man of science placed the stamp of character on this new institution. By his keen and quick appreciation and strong support that institution which Professor Egleston started became a great success.

JOHN A. CHURCH.— I name Francis L. Vinton, a graduate of West Point, and afterwards an associate of Professor Egleston in the École de Mines of Paris, who gave the new institution of the School of Mines of Columbia College the prestige and solid value of his thorough professional training and brilliant intellect.

PIERRE DE PEYSTER RICKETTS.— I propose the name of Charles A. Joy, who so unselfishly volunteered from the College faculty to teach general chemistry in the School of Mines.

FREDERICK R. HUTTON.— It is my pleasant duty to propose the name of William Guy Peck, a West Point graduate; keen and clear-sighted mathematician; devoted and successful instructor; and for many years Professor of Mechanics in the School of Mines.

MICHAEL I. PUPIN.— I name Professor Ogden N. Rood, of the department of physics, one of the most picturesque figures in American science, and particularly in the science of Columbia University; a most profound speaker and most clear exploiter of the abstruse and difficult science of physics.

ROBERT M. RAYMOND.— I have the honor to name Professor Newberry, a powerful factor in the development and maintenance of the high standards of the School of Mines.

DANIEL E. MORAN.—Last, but not least, I name William D. Trowbridge, a graduate of West Point; Professor of Civil Engineering in the School of Mines; scientist, author, and a man of tender heart, devotedly attached to his friends and pupils in the School of Mines.

J. F. KEMP.— Now, let us rise and drink a silent toast in memory of these old friends and instructors. (The toast was drunk standing, in silence.)

PROFESSOR FRANCIS L. VINTON.

PROFESSOR CHARLES A. JOY.

PROFESSOR WILLIAM G. PECK.

PROFESSOR OGDEN N. ROOD.

Men of Columbia, we cannot be too thankful that we have still with us two of the founders of the School of Mines. Arthur Elliot will propose a toast to one of them, and W. F. Morgan to the other.

ARTHUR ELLIOT.— I propose a toast to the health of Charles F. Chandler (Great applause, followed by the singing of "For He's a Jolly Good Fellow!"). I would recall to your minds, that Professor Chandler was our first Dean and for thirty years the backbone in administration of the School of Mines. May he live forever!

WILLIAM FELLOWS MORGAN.— I propose the health of John Howard Van Amringe; strictest of disciplinarians, thorough teacher, a friend and counsellor for all time of Columbia men (Applause and three cheers for "Van Am.")

J. F. KEMP.— Somewhat more than a century ago, Napoleon reviewed his army in the presence of the pyramids and the Sphinx. With these mute witnesses of the past behind him he said: "Soldiers of France, forty centuries are looking down upon you!" But I say to you tonight, Men of Columbia, fifty divisions of time are looking down upon us. Napoleon had before him only the witnesses of his first divisions of time, but we have with us witnesses of all our fifty divisions of time, from dear Doctor Chandler to the Class of 1914. Napoleon had from the first of his centuries only the deaf and dumb Sphinx, but when I turn Doctor Chandler loose later in the evening you will find that he's no Sphinx (Laughter). Napoleon had the pyramids for his witnesses. The pyramids begin large but they end in nothing but "hot air." The School of Mines began small but has spread over the whole earth. The School of Mines started in a broom factory. I never appreciated or understood until tonight what was the design of Providence in that particular form of its start; but since looking into the intelligent and seemingly prosperous and happy faces of the Early Eighties and of the Older Graduates I am of the belief that it was started in that humble way and under those conditions in order that its graduates might be taught to "make a clean sweep." Times have changed greatly since those days. We now find ourselves on Morningside Heights, a very different place from 49th Street and Fourth Avenue. Sometimes those who write the his-

tory of philosophy, and point out new lessons in the meaning of things, are likened to the tall mountain summits whose peaks catch the first rays of the morning sun, while all the country around is yet enshrouded in night. Let us hope that this typifies the mission of Columbia in this great city.

We have with us tonight some guests to whom I am anxious to say a word of welcome. We are proud to have Dr. Friedrich Kolbeck, from the ancient mining academy in Freiberg. No mining engineer lands on the continent of Europe without turning his face towards Freiberg, as the Mohammedan turns towards Mecca. It is the shrine of his faith. We are proud also to have with us Thomas Arthur Rickard, representative of the Royal School of Mines, London. We recall that Huxley taught in its laboratories, and that John Tyndall extended the new physics in one of its lecture rooms. We are also proud to welcome Hennen Jennings, who gave us so inspiring an address at the Convocation this morning. To him, and to Mr. Benjamin Thayer, of the American Institute of Mining Engineers, as representatives of the oldest American university, and as members in that little group of Harvard men who are in the very forefront of mining progress in America, I desire to say Welcome! We are also proud to have with us so many of the Alumni of the College. We are all marching on together, with our faces pointed in the same direction, and in the presence of this audience I may be permitted to use an engineering simile. When we see a great plant, with its complicated machinery, its revolving shafts and whirling wheels and interweaving shuttles, we know that somewhere in that machine there is an engine which is the source of its movement and the supporter of all its activities. Men and brethren of Columbia, I have the honor to present to you the prime mover of Columbia University, President Nicholas Murray Butler (Great applause).

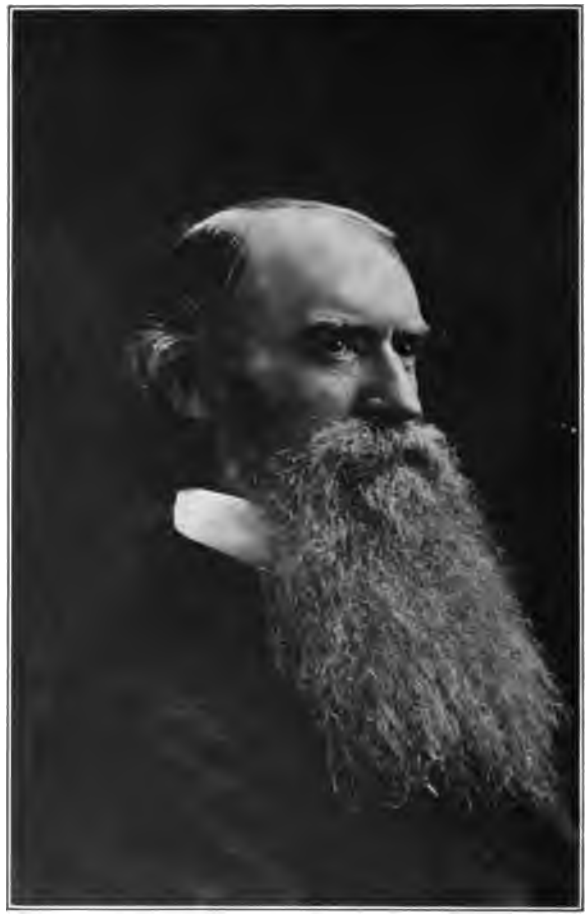
PRESIDENT BUTLER.— My mind goes back in the presence of this audience over two-thirds of the period that we are commemorating. I see a slow-moving horse car, moving up the avenue called Madison. I see the smoky steam engine, at a time when electricity was still nothing more than a Greek root, moving into the station at 42d Street. I see a cattleyard surrounded by a four-bar fence, whitewashed, where now rises the Ritz-Carlton Hotel. I see a few

scattered houses here and there, and then on the summit to the right a building with a noble portico, in front a stately row of elms and

COLUMBIA COLLEGE ABOUT 1860. PRESIDENT BARNARD'S RESIDENCE AT RIGHT.

a bit of green lawn, some adjoining buildings, and a group of eager and ambitious youth coming some time after the morning sun.

If I keep looking, I see a stately form, moving slowly from east to west under those elms, wearing a broadcloth frock coat, with glasses and snow-white beard, a mien of exceptional dignity and



PROFESSOR JOHN S. NEWBERRY.

power, and I see the person of our great President Barnard. I keep looking, and I see a stocky, stalwart form moving quickly across the campus, wearing a frock coat and an air of great concentration, heading toward the northeast corner, and I identify Tommy Rocks. Soon there comes another dignified man, with a long beard and glasses and a quizzical look in the eye, and I see

Dr. Newberry. Behind him is a tall, solemn figure with long hair, the inevitable red tie, and an undetachable ulster, and I behold Ogden Rood.

Pretty soon there comes a shorter, stouter man, with a stick at

EGLESTON.

VINTON.

right angles under his arm, eye-glasses well down on his nose, yesterday's chalk-marks on his coat, and I see Billy Peck. All these men seem to be old, but there are two others that are surprisingly young. One comes bustling along, with little slips of yellow paper

CHANDLER.

VAN AMRINGE.

in the upper left hand pocket of his "wescot," on which he jots down anything that occurs to him, or that is said to him, of such importance that he does not wish to forget it, with a series of numbered stories in his pocket and a solemn warning that, in no circumstances must story No. 27 be repeated because he wants to use it this time next year; and so I see the Dean, the Bursar, the Registrar, in short "the whole thing," Chandler (Great laughter and applause). Here comes another — blue eyes, glasses, tremendously severe looking, yet concealing the tenderest heart that ever was, who asks you to go to the blackboard, and after you have

gone there and stood for a while looking at the board, comes back to you and says, "Well, draw the figure." "I can't, Professor," you stammer. "Well, write your name; you can do that!" That's "Van Am."

I see all that vision, my friends, as if it were but yesterday. No amount of mathematics or study of the calendar can make me believe that nearly forty years have come and gone since we saw these men, since we walked under those elms, since we left that slow-moving horse car, since we built up the associations and the memories that bring us here tonight. Believe me, it was yesterday. It is the yesterday of our youth that has grown, perhaps, into something different, but yet we clutch it with tenderness and affection because of its everlasting reality. We cannot let go of it if we would, and we would not if we could. And as we stand here tonight and gaze back over those fifty years for some of us, forty for others, thirty for others, and for some but twenty years or less, believe me, fellow Columbians, there is another splendid army back where we were. There is another generation of young students of mining who are standing where you and I stood forty or more years ago. They have their heroes, their affections, their associations; and we can only hope that theirs will mean as much to them as ours mean to us (Great applause).

PROFESSOR KEMP next called on Charley Sawyer to read the following poem, written by Charles Buxton Going:

Now, here's to the Old Forty-Niner,
And here's to the Young Morningside —
A toast to both A.B. and Miner,
In friendship and sonship allied;

A sonship no one here would barter
For wealth of material things —
Right Royal is our Alma Mater,
And we are descended from Kings.

And kinglike in leading, my brothers,
The Mines, half a century back,
Blazed trails of world-conquest for others,
Who follow, with honor, our track.

So whether we toiled in the Maison
de Punk, in the years long ago,
Or whether we spent student days on
The Heights that the younger men know —

Down here, or on Morningside yonder —
  What's mere fifty years between friends?
It makes us just fifty years fonder!
  Why, boys, when this universe ends

And Gabriel rolls up the curtain
  That hides the Hereafter from view,
The first thing, I'm perfectly certain,
  Columbia alumni will do

Will be this: they will listen politely
  While angel harp-soloists strum
Till they hear, maybe far off, but brightly,
  The sound of a Fife and a Drum,

And fragments of heavenly clamor
  That roll down the long Golden Way
Like "Who are the Stuff?" or "Van Am!" or
  C-O L-U-M B-I-A!

And we'll organize orders in Heaven —
  "Old Seraphs," or "Late Cherubim,"
Till the Great City seethes with our leaven
  And joins in our cheering with vim,

And the wandering spirits that hear it
  Reply with a jubilant shout —
For, boys, the Columbia spirit
  Will flame when the stars are burned out!

Then here's to Our Guests, whom we honor;
  Our Chums may we oft meet again;
And Columbia — blessings upon her —
  To COLUMBIA, MOTHER OF MEN!

J. F. KEMP.— It is a source of deep regret that we have not with us tonight the senior professor in the Faculty of Applied Science, Professor Henry Smith Munroe, but we are fortunate in having a message from him, cabled from Switzerland, which I will read to you:

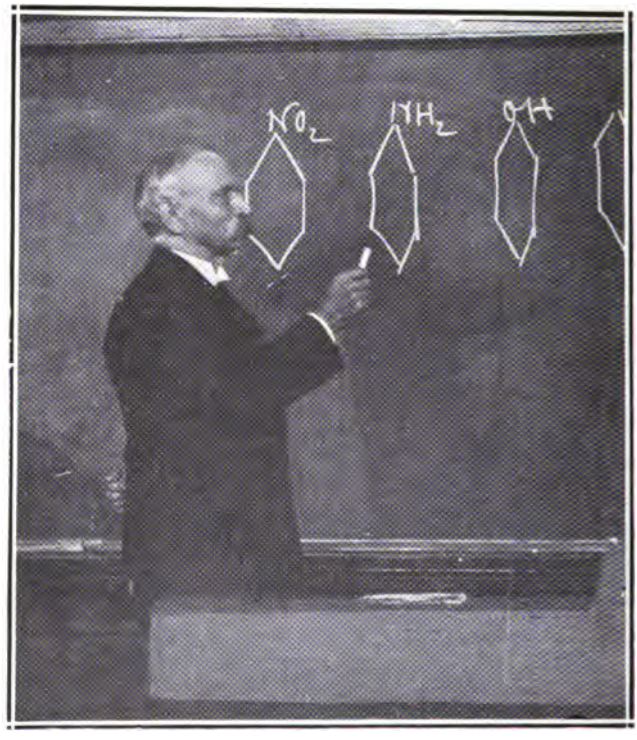
The greatest disappointment of my life. Greetings to my old students, fellow alumni, colleagues and friends. May the School of Mines continue its great work for centuries.— MUNROE.

We also have a message from Jim Livingston:

Deeply regret my enforced absence to-night. Congratulations on successful celebration.— JAMES LIVINGSTON.

And another from S. S. Fowler:

The western branch of Canadian Mining Institute, recognizing the splendid achievements of the Columbia School of Mines, desires me to extend congratulations upon completion of fifty years of successful effort, and hopes that the School's influence for good may continue *ad infinitum*.— S. S. FOWLER, Chairman.



PROFESSOR CHANDLER AT LECTURE.

All of you who have studied geology know that sometimes in the ancient strata we find a species that persists, no matter what happens to the other forms of life. You all know that in botany we have certain plants which spring ever anew from their roots, and are in no way affected by the colds of Winter. We call these plants "hardy perennials." I have the honor to present to you a combination of the persistent specie and the hardy perennial, Dr. Charles Frederick Chandler (Applause).

DR. CHANDLER.— Can there be a happier moment for an old pro-

fessor than to greet five or six hundred of his boys, his pupils, gathered together? Every one of you has studied in my lecture room two years, and many of you four years (Laughter). Every one of you is my friend, and every one of you knows me better than I do myself. There's no use of my putting on any "frills" or making any false pretences; you would see through them all. I don't believe there's a happier man on the earth than I am tonight, to see you all come together to celebrate this fiftieth anniversary of the founding of the School of Mines.

When the School of Mines was founded, fifty years ago, many

MINES.

ENGINEERING.

people in the city of New York thought it was a very foolish proposition, and few there were who believed in its ultimate success. Some said "there are no mines," and others said "New York will never support an institution of higher education." As J. D. Whitney said before the legislature of California when he refuted something which had been said to him, "I deny the allegation and I defy the alligator!"

The School of Mines was a success from the day it was opened, and the reason was that Tom Eglestion conceived the proper system on which such a school should be established. The plan that he drew up as far back as 1863 is the plan that has been persistently adhered to, and has led to the successful practise of his ideas.

A few years ago I happened to be in London, and Dr. Ludwig Mond, the most distinguished chemical engineer in Great Britain, invited me to dinner. In the course of the dinner he said to me "Dr. Chandler, I want to tell you something that I know will please you." I said, "Do you really, then shoot!" He said, "I have a

great many investments in all parts of the world, and my son and I have been around the earth visiting our mines and metallurgical establishments. We went to South Africa, Australia, New Zealand, South America, Mexico, California and other countries. Having met you, and having visited Columbia University, I was particularly interested in making the acquaintance of all the mining engineers who came in my way; and you will be surprised when I tell you that the most distinguished mining engineers whom I met, wherever I went, hailed from the Columbia School of Mines."

Now, the reason why these men have distinguished themselves

HAVEMEYER.

SCHERMERHORN

is because Egleston planned a system which cannot be improved upon, and in all these fifty years we have stuck to his plan and carried out his ideas. There were many scientific schools before the School of Mines, good schools, but they all attempted to do two things at once, which were practically incompatible. They undertook to give a man a general education and a professional education at the same time. They crowded out the higher professional studies in order to make room for what the college professor calls "the humanities." They introduced rhetoric and logic and various other things which they said everybody ought to know. We never denied their statements, but we said that this must be a professional school, a school of mines. The course is four years, and if we take a third or a half of that time for subjects which are not pertinent to the profession of mining engineering we must crowd out an equivalent quantity of professional work. There were many discussions in the Faculty of Columbia as to the propriety of this. A Greek professor said that a man who has not

acquired a knowledge of Greek has no education at all, and I answered that a man who does not know the composition of the air he breathes or the water he drinks has no education at all. And, although great pressure was brought to bear upon us to introduce into our curriculum a variety of most interesting subjects, subjects which everybody would like to know something about, we always resisted steadfastly.

As an illustration of the advantage of this plan, let me tell you a little incident that occurred two or three years ago before I resigned. Three young men came into my office and said to me,

FAYERWEATHER. AVERY.

"Professor Chandler, we have just entered the third year in the School of Mines and we find that you require that a graduate must have passed in every subject taught in the four years' course before he can obtain his degree. Now, we have never taken your second year in applied chemistry; therefore, we can't pass your examination. If we attend your lectures we shall be a year longer in passing. What shall we do?" I asked, "How did you ever get into the third year of the mining course?" They replied, "We have graduated in mining engineering at two of the leading universities in this country." Two of them, it seems, came from one university and one from another university. I said, "If you have graduated as mining engineers, why do you wish to spend two more years at Columbia?" They replied, "We have not studied the subjects you teach in the third and fourth years. We had to study the 'humanities' at the other universities, and we came here to complete our mining education; besides that, we want your degree!" That, I take it, is the best endorsement of the wisdom of Pro-

fessor Egleston when he planned a purely professional school.

Something else turned up the other day which interested me very much and aroused my ire. We have recently added two years to the course and made it a six years' course, and one of the younger professors at a dinner expressed dissatisfaction that we had now raised the School of Mines to the standard of the medical college. That was too much for me. When my turn came I said that I would tell him, for the benefit of his information, what the standard of the medical college was long after the School of Mines had adopted its standard. When I became professor in the medical college, I found that the sessions consisted of two terms of five months each, with no examination for admission, no roll-call to secure attendance at the lectures, no semi-annual or annual examinations; but at the end of the two five-months' courses, each professor hid himself in his den, and the students formed a line outside and one by one came in for a two minutes' talk. They generally said to me, "You know we can't be expected to know much about chemistry, so you must be easy on us." Two or three, or possibly five minutes' conversation with each professor was the only examination there was, and if a student succeeded in passing five out of the seven subjects he received his degree of M. D. He might fail in the theory and practise of medicine; he might fail in surgery, but he would receive his degree of M. D., and was let loose on the public "for better or for worse." Many of these young men, by great industry, with further study, and with the knowledge and skill acquired by experience, became distinguished surgeons and practitioners. I took the ground that as chemistry and mining engineering are exact subjects it takes four years to make a chemist or an engineer. Medicine was only an art, very uncertain at best, and I could not see how they could make a physician or a surgeon in two terms of five months. We set the example for the School of Medicine, and year by year they have raised its standard and finally brought it up to that of the School of Mines. The School of Mines adopted the highest standard at the outset. It has insisted on it always, and every year has still further raised its standard, until I do not believe there is an institution in the world maintaining a higher standard than the School of Mines. I wish, finally, to say a word concerning our dis-

tinguished president. Dr. Butler has done everything in his power since he became President of this University to help the School of Mines in every way, and we are much indebted to him therefor.

PRESENT SCHOOL OF MINES, FROM THE CAMPUS.
Gift of Adolph Lewisohn.

Not a question has ever come up regarding the management of the School of Mines, or its support, in which Dr. Butler has not manifested the greatest interest and the clearest insight into the wants and demands of the School. The School of Mines, in short, has never had a friend who has done more to advance its interests than President Butler (Applause).

In conclusion, I can imagine no greater pleasure for a man in

my position than to see such a host of distinguished men who are willing to claim relationship with their old professor. I thank Heaven for permitting me to live to see this semi-centennial of the School of Mines, and to enjoy the feeling that every effort which my colleagues and myself have made for its benefit has been rewarded with such success. (Great applause.)

J. F. KEMP.— I mentioned earlier in the evening how the School of Mines had its beginning. It started in a broom factory, but the next speaker, Mr. Adolph Lewisohn, left it in a palace.

ADOLPH LEWISOHN.— The mining industry is one of the most important factors in the development and improvement of this or any other country. The profession of mining engineering calls for the highest efficiency and character. We have with us tonight the best of mining engineers; how could they be otherwise with the superb training they have undergone at the famous Columbia School of Mines? There is still a great future before us in mining engineering; we have as yet but scratched the surface of the earth. The mines of the future may be of a lower grade than those of today, but there will be improved facilities for mining and less waste than at present. I wish the School of Mines continued success for generations to come in its great mission of furthering the arts of mining and metallurgy, and in the education and training of men who will be good and useful citizens in the development of our great country. (Applause, and "three cheers for Mr. Lewisohn!")

J. F. KEMP.— We still feel ringing in our ears the words we have heard this morning, this afternoon, and tonight. There is no one of us so dull as not to gather some inspiration from among all the things that have been said. Let us, then, as the result of this celebration, pull our belts a hole tighter and devote ourselves to our several professions with renewed zeal. It remains only for me to adjourn this meeting, to gather again fifty years from tonight.

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